AGRO-PROCESSING BY-PRODUCTS MANAGEMENT BY UTILIZATION: THE CASE OF COFFEE HUSK COMPOSTING IN SOUTH WESTERN ETHIOPIA

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AGRO-PROCESSING BY-PRODUCTS MANAGEMENT BY UTILIZATION: THE CASE OF COFFEE HUSK COMPOSTING IN SOUTH WESTERN ETHIOPIA

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By

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APPROVAL SHEET OF THESIS

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As Thesis research advisors, we herby certify that we have read and evaluated this Thesis prepared, under our guidance, by Solomon Girmay entitled: "**AGRO-PROCESSING BY-PRODUCTS MANAGEMENT BY UTILIZATION: THE CASE OF COFFEE HUSK COMPOSTING IN SOUTH WESTERN ETHIOPIA.** We recommend it be submitted as fulfilling the Thesis requirement.

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DEDICATION

This thesis work is dedicated to my beloved family and my beloved baby boy Leul Solomon.

STATEMENT OF AUTHOR

First, I declare that this thesis is my original work and all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree at the Jimma University College of Agriculture and Veterinary Medicine and is deposited at the University Library to be made available to borrowers under rules of the library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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BIOGRAPHICAL SKETCH

The author was born in May 06, 1980G.C in Alamata Wereda, Tigray. He attended his elementary school at Alamata Elementary School from 1985-1991 and his Secondary school at Tadagiwa Ethiopia Senior Secondary School from 1992-1999. Passing the Ethiopian Higher Education Entrance Qualification Certificate, he joined Hawassa University (Wondo Genet Forestry College) in 2000 and graduated in 2003 with B.Sc. degree in Forestry. Soon after graduation he was employed in Maychew Agricultural Technical and Vocational College as Junior Instructor during 2004-2006. In the years 2006-2009 he served in Alamata Wereda Agriculture and Rural Development office as Forestry expert. Between 2009-April 2010 he worked in Diamond Coffee Development Plc., Kaffa Zone as farm manager. He joined the School of Graduate Studies at Jimma University in September 2010 to pursue his M.Sc degree in Natural Resources Management; specializing in Water Shade Management.

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ABREVIATIONS

ANOVA …….Analysis of Variance

BPEDORS …….Bureau of Planning and Economic Development of Oromia Regional State

EARO…….Ethiopian Agricultural Research Organization

FRC…….Forestry Research Center

JUCAVM ……..Jimma University College of Agriculture and Veterinary Medicine

RCBD ……Randomized Complete Block Design

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ABSTRACT

Management of Agricultural byproducts, such as coffee husk, in developing countries is challenging due to their high transportation and handling costs and hence becoming major sources of environmental pollution. The commonly practiced management options, such as mulching and conventional composting, have several limitations. Therefore, the use of earth worms, and Effective Microorganism (EM) as a solution in coffee husk composting were hypothesized to be efficient in reducing compost maturity period while increasing the final compost quality. It was also hypothesized that coffee husk vermiwash enhances plant growth attributes depending on the rates used. In this study, two independent experiments were conducted from March 01-April 30, 2012. The first experiment was conducted to evaluate the effect of coffee husk compost types and their rate of application on seed germination and seedling growth of two commercially important tree species, Moringa stenopetala (Bak.) and Jatropha curcas (L.). The second experiment was conducted to evaluate the effect of coffee husk vermiwash at different concentrations on seed germination and seedling growth of the two species. For the first experiment, three factors were tested: Factor1, compost type (vermicompost (CHVC), EM compost (CHEMC), and conventional compost (CHCC)); factor 2, plant species (M. stenopetala, and J.curcas), and factor 3, compost rate (0, 10, 20, 30, and 40 %(v/v)). The experiment was arranged in 2x3x5 factorial in three blocks. For the second experiment, coffee husk vermiwash (CHVW) concentration at five levels was tested on two plant species in 2x5 factorial in three blocks. Both experiments were made with randomized complete Block Design (RCBD). Seedling growth attributes were recorded as response variables in both experiments. The results revealed that incorporation of the three compost types significantly ($P<0.0001$) improved the soil physico-chemical properties. Similarly, incorporation of the three compost types significantly enhanced all seedling growth parameters. Chlorophyll a and b were significantly higher due to CHVC application in M.stenopetala, which was statistically at par with CHCC and CHEMC, and J.curcas due to CHVC and CHEMC. The highest plant height was recorded from CHCC application. Maximum leaf number (7.05) and stem girth (6.83) were also observed from CHVC application. Irrespective of coffee husk compost (CHC) types, J. curcas showed the highest shoot fresh weight at 30 and 40 % and shoot dry weight at 20, 30, and 40 % (v/v) compared to non amended control. Application of CHVC at 40 % rate gave the maximum seedling root length of both species. Application of CHC at 20 and 30 %(v/v) rate enhanced root dry weight, but the value declined beyond 30%. Foliar spray of CHVW at 30 and 40 %(v/v) significantly ($P<0.0001$) contributed to maximum value of leaf chlorophyll b, plant height , stem girth thickness, shoot dry and root fresh weight. In conclusions, coffee husk vermicompost improved most of the soil physico-chemical properties and significantly improved the growth of seedlings compared to the other two composts. Utilization of CHVW foliar spray at 30 and 40 %(v/v) was found to be an economical. Therefore, coffee husk compost, which demands low labour and simple technology input, can be an opportunity in coffee growing areas of the country for better seedling growth and production in nurseries. Finally in order to enhance the microbial decomposition and ensure sustainable utilization of coffee husk while reducing environmental pollution, incorporation of bulking agents in vermicomposting and nutritional quality analysis of vermicompost and vermiwash need further study.

1. INTRODUCTION

Globally, 140 billion metric tons of biomass is generated every year from agriculture in different forms of residual stalks, straw, leaves, roots, husk, nut or seed shells, wood and animal husbandry waste (UNEP, 2009). The dominant industries in developing countries are agriculture-based, where the byproducts are source of serious environmental pollution (Krusea *et al.,* 2010). The high collection, transportation, and handling costs associated with agricultural residues are the foremost obstacles to the various uses of these wastes. Straws and husks are hard to pack (Falvey, 1996). Land disposal and direct combustion remain the cheapest way to get rid of agricultural residual wastes (Kelleher *et al.,* 2002). As a result, a considerable amount of byproducts (*e.g.,* from coffee, sugarcane and brewery industries) are dumped to both terrestrial and aquatic ecosystems (Mahimairaja *et al*., 2005).With regard to this, coffee pulp and husks are the prime sources of agricultural wastes in developing countries specifically in Ethiopia. These solid biogenic residues, given the high amounts generated, cause environmental pollution, freshwater eutrophication and increased spread of water-borne diseases, since they constitute a source of severe contaminants (Lagemaat and Pyle, 2001). Coffee husk in Ethiopia, the major focus of the present study, particularly in the coffee growing regions of south west, is the hazardous pollutant responsible for the contamination and degradation of the ecosystem (Kahsay, 2009).

The rational utilization of coffee husk has some ecological and economic implications (Kivaisi *et al.,* 2010) that may become evident as its use increases. Some of the main alternative uses of coffee by-products include animal feed (Pandey *et al*., 2000), production of alcohol, biogas (Kivais, 2002), soil mulch (Tadesse *et al.*, 2007), charcoal and heat energy (UNEP, 2009; Wondwossen, 2009), mushroom production (Kivaisi *et al*., 2010), compost (Gezahegn *et al.,* 2011), vermicompost (Gezahegn *et al*., 2012) and toxic Chromium adsorption (Ahalya *et al.,* 2010). Coffee husk has adsorption capacity of about 50 milligrams hexavalent (60%) chromium per gram of coffee husk. However, these applications utilize only a fraction of coffee husk available and are not technically very efficient. Technically, efficient alternative agricultural uses of coffee husk will enhance the efficiency of the whole agricultural production process and can displace fossil fuels and help reduce green house gas

(GHG) emissions (UNEP, 2009), since they contain abundantly useful organic materials. The application of environmentally sound coffee husk disposal methods requires an understanding of the range of waste utilization, treatment and recycling options.

Mulching and composting coffee husk are the common conventional agronomic utilization methods. Composting is a natural decomposition process of organic wastes under controlled conditions into extremely useful humus-like substance by various micro-organisms including bacteria, fungi and actinomycetes in the presence of oxygen (Misra *et al*., 2003). However, direct and inappropriately-timed application of coffee husk mulching to agricultural fields causes serious environmental problems, including the release of excessive amounts of tannins and phenols in soils, which could inhibit plant root growth (Farah and Trugo, 2006). Moreover, odor emission and the presence of pathogens and its plant growth impairment are some considerable limitations of mulch, which make it less suitable for land application. On the other hand, coffee husk compost maturity may take more than about 5-6 months time for use (Sathianarayanan and Khan, 2008), which can be considered as a limitation to exploit its nutritive potential.

Therefore, this situation demands for a suitable methodology to reduce environmental problems associated with its management. Coffee husk can be converted to useful products through vermicomposting (Gezahegn *et al*., 2012) and use of Effective Microorganism (EM) technology (Higa and Wididana, 1991). Vermicomposting transforms agricultural residues in to a safer and more stabilized product that can be used as a source of nutrients and soil conditioner in agricultural applications while eliminating environmental pollutants (Atiyeh *et al.,* 2002; Suthar and Singh, 2008). Vermicompost contains a considerable amount of some essential plant micronutrients responsible for better plant growth and productivity and can considerably contribute to nutrient recovery (Suthar 2009; Dominguez and Aira, 2012). Vermicompost has much finer structure, outstanding chemical and biological properties with 'plant growth regulators', and nutrients than ordinary compost does in readily forms available for plant uptake, since it is enriched with diverse microbial populations (Pathma and Sakthivel, 2012). Moreover, vermicompost contributes for significant reduction of carbon dioxide (CO_2) emissions and energy inputs, substitutes or reduces dependency on the use of

synthetic fertilizers or other products, alleviate eutrophication and associated human health problems (Foucherot and Bellassen, 2011; Papathanasiou *et al*., 2012).

Vermiwash is a clear and transparent, pale yellow coloured fluid collected after the passage of water through a column of worm action (vermicomposting). It contains excretory products and mucus secretion of earthworms rich in amino acids, vitamins, nutrients like nitrogen, potassium, magnesium, zinc, calcium, iron and copper and some growth hormones like 'auxins', 'cytokinins'. It also contains plenty of nitrogen-fixing and phosphate solubilising bacteria (nitrosomonas, nitrobacter and actinomycetes). Vermiwash, therefore, has great 'growth promoting' as well as 'pest killing' properties (Sinha *et al*., 2010).

The use of effective microorganisms (EM) technology provides benefits in recycling agricultural waste, serves as plant fertilizer, detoxifies soils, kills certain pathogens and prevents insects infestation in crops (Higa and Wididana, 1991). The benefit of EM in composting is its rapid action that reduces the composting period up to three weeks. It does not emit gases of offensive smells, such as hydrogen sulfide and ammonia, enhances soil fertility and soil health, improves soil biodiversity and reduces ecological risks (Hoornweg *et al.,* 2000; Misra *et al*., 2003). Therefore, plant residue composting with EM can produce higher quality compost helpful in soil management for sustainable cultivation of any crop (Sekeran *et al*., 2005).

1.1. Statement of the Problem

Environmental degradation particularly pollution of terrestrial and aquatic ecosystem including their biodiversity loss has gained growing concern globally and locally as a result of human malpractice with little or no environmental management system (Millennium Ecosystem Assessment, 2005). Improper use of inorganic fertilizers, poor sanitation such as from coffee processing plants and lack of sanitation policy measures and weak government commitment are among responsible factors (Kebede *et al*., 2002). Hence, vermicompost, vermiwash and EM technology may be the best alternatives for management of coffee husk for better pollution control and utilize as soil fertility. Both utilization approaches are

witnessed to contribute significant potential to recycle biogenic residues to toxic free and suitable for farm lands applications. They add values, reduce maturation time, increase compost quality, conserve natural resources and the environment, enhance microbial and enzymatic activities in soils, improve soil fertility and soil health, improve soil biodiversity, increase crop growth and yield while also creating healthy environment (Sinha *et al.,* 2009).

However, there is information gap on how to make maximum benefit out of managing coffee husk thereby create a clean environment and improve soil fertility. The use of coffee husk as substrate through vermicomposting, vermiwash and EM has not been well studied in Ethiopia for various reasons. Therefore, land managers and farmers in Ethiopia find difficult to recycle biogenic residues to make use as soil amendment. Information is required on appropriate vermicompost, vermiwash and EM coffee husk compost.

Multipurpose agro forestry trees and biofuels can address the issue of food insecurity, high energy costs associated with grain food deficit and import based fossil fuel energy security. *Moringa stenopetala* (Bak.) and *Jatropha curcas* (L.) are among the most important trees/shrubs to be considered vital in response to the forementioned problems in Ethiopia. *M.stenopetala* is one of a unique strategic multipurpose indigenous agro forestry tree in drought prone areas of Ethiopia with an extremely valuable source of nutrition for people of all ages (Dechasa *et al.*, 2006). It is also a contingency crop in frequently drought prone areas which plays a vital role for household food security, as source of income, medicine, fodder, fuel and shade tree all year round (Tenaye *et al.,* 2009). Also, *J.curcas* is one of the perennial shrubs producing seeds with high oil content for biofuel. It is a fast growing, drought tolerant source of biofuel plant without compromising food security (Salé and Dewes, 2009). However, tangible information about their proper agronomic practices for economic food and biofuel production is scarce. Therefore, investigating the organic fertilizer demand of these two species is of the prime interest of the researcher.

1.2. Purpose of the Study

Though conventional compost, vermicompost, EM compost, and vermiwash are said to have beneficial role on many aspects of the environment, there exists difference in their physicochemical property. This is mainly due to the unique decomposing ability of microorganisms, earth worms and EM. Therefore, the purpose of this study was to evaluate the comparative effects of different coffee husk composts and vermiwash foliar spray on seedling growth of *M.stenopetala* and *J.curcas* under lath house condition.

1.3 General Objective

The general objective of the present study was to evaluate the effect of coffee husk compost and vermiwash on seedling growth of *Moringa stenopetala* (Bak.) and *Jatropha curcas* (L.)

Specific objectives

1. To evaluate the comparative effects of different coffee husk composts on seedling growth of *Moringa stenopetala* (Bak.) and *Jatropha curcas* (L.)
2. To evaluate vermiwash foliar spray effect on seedling growth of *Moringa stenopetala* (Bak.) and *Jatropha curcas* (L.)
3. To determine the effect of coffee husk composts on soil chemical properties.

2. LITERATURE REVIEW

2.1 Methods of Coffee Processing and their By-Products

There are two major methods of coffee cherry processing: dry and wet processing. In dry coffee processing red berries are sorted and spread out in the sun on large concrete or brick patios or on matting. They are raked regularly to avoid fermentation and to expose them evenly to the sun's rays. It can take up to four weeks for moisture content of each berry to reach an optimum level (12%). On the other hand, wet coffee processing requires only red berries. Generated solid residues in dry processing method are coffee husks (outer skin + pulp + parchment) and silver skin; while the byproducts of wet coffee processing are coffee pulp, parchment, and mucilage (Subedi, 2011). For every kg of coffee beans produced, approximately 1 kg of husks are generated during dry processing (Franca and Olivera, 2009).

2.2 Physicochemical characteristics of coffee husk

Coffee husk is rich in organic substances, such as carbohydrates, proteins and minerals which can contribute to its potential use as industrial raw material and animal feedstuffs (Mazzafera, 2002). However, the low bulk density, high carbon to nitrogen ratio (C/N) values, the presence of appreciable quantities of toxic substances, such as tannins, caffeine, lignin, polyphenols and potassium in the coffee husk limit its beneficial utility (Mazzafera, 2002). These properties make coffee husk management an environmental challenge leading to environmental pollution problem (Kahsay, 2009; Nayak *et al.,* 2012).

2.3 Alternative Utilization of Coffee Husk

The rich organic matter content of coffee husk makes it an ideal substrate for microbial processes for the production of mushroom (Kivaisi *et al.,* 2010), biofertilizer such as compost (Gezahegn *et al.,* 2011), and vermicompost (Gezahegn *et al*., 2012), alcohol, biogas (Kivais, 2002), briquettes charcoal and heat energy (Wondwossen, 2009), and animal feed. However, still these applications of coffee husk utilize only a fraction of available quantity and are not technically very efficient (Pandey *et al.,* 2000).

2.3.1 Mushroom production

Coffee husk can be utilized for edible mushroom cultivation (Leifa *et al.,* 2000; Kivaisi *et al.,* 2010). Treatment of the coffee husk with hot water can increase the useful utilization for mushroom production and increases the protein content while decreasing the caffeine, tannin, and fiber content of the substrates (Leifa *et al.,* 2000). Also for better mushroom mycelium production fermentation or detoxification can reduce or avoid the negative effect of the large amounts of caffeine and tannins. Degradation by fermenting microorganisms and bio remediation using Pleurotus species are among the several possible methods for caffeine removal and make suitable substrate for mushrooms growth (Kurtzman, 2010).

2.3.2. Biogas production

Coffee husk can be used as a raw material for the production of biogas (mainly carbon dioxide and methane gas) in anaerobic digestion. Its organic matter richness makes coffee husk an ideal substrate for microbial processes for the production of value-added thermal energy product (Welzenbach, 2009). The bioconversion processes is mostly employed through controlled anaerobic solid state fermentation while offering a valuable option for emission prevention. Successful production of biogas from coffee husks requires bulking agents such as cow dung (Juciūnas *et al*., 2011). Therefore, the micro-organisms (mainly bacteria) in the mixture will produce biogas after a short start-up period depending on the temperature of the mixture thermophilic (50°C-70°C) or mesophilic (20°C–45°C) (Schnurer and Jarvis, 2010). Consequently, with adequate storage, biogas digestion from coffee husk could add value and reduce greenhouse gas emissions, unpleasant odors and attraction of flies and insects (Kivaisi *et al.,* 2010). Thus, anaerobic digestion could be considered as a useful way to utilize it effectively.

2.3.3. Briquette production

Briquetting, the process of biomass densification represents a set of technologies for the conversion of biomass into a fuel. Raw materials for briquetting can be waste from agro-

industries such as coffee husk and saw dust (Kivaisi *et al*., 2010). Briquetting improves the transportation, handling and storage characteristics of the materials (Elinge *et al.,* 2011). This technology can help in expanding the use of biomass in energy production, since densification improves the volumetric caloric value of a fuel, reduces the cost of transport and can help in improving the fuel situation in rural areas and associated pollution.

2.3.4 Mulch

Direct application of coffee husk as soil mulch allows the recovery of depleted soil nutrients, since it contains different mineral elements in different concentrations (Bolwig, 2012). Uniform application of coffee husk mulch conserves considerable amount of soil moisture, increases total N and soil pH and consequently improves plant productivity. Coffee husk mulch conserves soil moisture enough to significantly promote vegetative growth in pineapples and controls weeds (Tadesse *et al.*, 2007). Mulches can also check soil erosion, and stabilizes soil temperature (Gardner *et al.*, 1999).

2.4. Biology and Ecology of Earthworms

2.4.1. Biology

Earthworms belonging to Phylum Annelida, Class Chaetopoda, and Order Oligochaeta and, occupy a unique position in animal kingdom. They are the first group of multi-cellular, eucoelomate invertebrates who have succeeded to inhabit terrestrial environment, and form major soil macro fauna (Kale and Karmegam, 2010). An earthworm has a digestive tube housed within a thick cylindrical muscular tube that forms the body. Its body is divided into segments, and furrows on the surface which mark the division between each segment. The first segment encloses the mouth, and has a fleshy, muscular lobe on the top. This lobe can be pulled in to seal the mouth, or extended forward to probe the immediate surroundings. All segments, except the first, have eight retractable bristles which help the earthworm to hold surfaces as it moves.

2.4.2. Ecology

Earthworms by virtue of their activity, contribute to the physical and chemical alterations in the soil leading to increased soil fertility and plant growth (Boguzas *et al.,* 2010). Earthworm species fall into three distinct ecological groups based on feeding and burrowing: epigeic, endogeic, and anecic (Neilson *et al.,* 2000*)*. Epigeic earthworms live and feed on the soil leaf litter surface. They move horizontally through leaf litter or compost with little burrowing into the soil. These worms are characteristically small and are not found in low organic matter soils (e.g. *Eisenia fetida*). Endogeic (shallow dwelling) earthworms are active in mineral topsoil layers and associated organic matter (e.g. *Allolobophora chlorotica*). Anecic (deep burrowing) earthworms live in permanent, nearly vertical burrows that may extend several feet into the soil (*E.g*. *Lumbricus terrestris*) (Butt and Lowe, 2011).

2.4.3. Suitable earthworm species (*Eisenia fetida*) for vermicomposting

The vermicompost produced using different species of earthworms varies in its nutrient composition (Sharma *et al.,* 2005). So, the selection of the suitable species for particular vermicomposting application is important. Epigeic earthworm species are therefore used widely for the purpose of organic waste vermicomposting more acceptable than others (Suthar and Singh, 2008). *Eisenia fetida,* popularly known as red wriggler worms are perhaps the most widely used for vermicomposting. They are prolific breeders, maintaining a high reproduction rate under favorable moisture and food availability. They also show high metabolic activity and hence are particularly useful for vermicomposting. They also have wide usages for various toxicological studies as test worm (Sharma *et al.,* 2005). Mature individuals can attain up to 1.5 g body weight. Each mature worm on average produces one cocoon every third day and from each cocoon emerge 1 to 3 individuals on hatching within 23 days.

2.5. Vermicomposting Technology

Vermin is the Latin word for ‘worm’. Vermicomposting refers to the production of plant nutrient rich excreta of worms. It recycles organic matters in to useful soil amendingand organic nutrient rich compost using earth worms. It is a solid phase decomposition of organic residues in aerobic environment by exploiting the optimum biological activity of earthworms and micro-organisms (Suthar and Singh, 2008). The process depends upon the earthworms to fragment, mix and promote microbial activity in the organic waste material (Sharma *et al.,* 2005). Compared to the thermal composting, vermicomposting generates a product with lower mass and high humus content, shortens processing time, and less likely phytotoxicity with greater fertilizer value (Suthar, 2007).

2.5.1. Basic vermicomposting process

Earthworm participation enhances natural biodegradation and decomposition of organic waste from 60 to 80% (Sinha *et al*., 2002). Given the optimum conditions of temperature (20–30^{o}C) and moisture (60–70%), about 5 kg of worms (numbering approximately 10,000) can vermin about 1 ton of waste into vermicompost in just 30 days. When compared to the normal aerobic composting systems, it takes nearly half the time to convert waste into compost and the process becomes faster with time as the worms grow (Sinha *et al.*, 2009). During vermin composting process, there are three different phases: thermophilic, mesophilic, and maturing phase (Frederickson *et al.,* 2006). Thermophilic is an initial pre-composting phase. At this stage, the organic waste is pre-composted at least for about 15 days before being fed by earthworms. It degrades readily decomposable compounds and eliminates potential volatile substances, which may be toxic to earthworms (Mupondi *et al*., 2010). During mesophilic phase, the next decomposition process, earthworms break up organic matter and enhance microbial activities and condition organic waste materials for the formation of organic manures (Sathianarayanan and Kan, 2008). The final step is maturing and stabilization phase. Earthworms at this stage accomplish both physical and biochemical processes. Physical participation in degrading the organic substances results in fragmentation thereby increasing the surface area for further microbial colonization (Sharma *et al.,* 2005). Biochemical changes

in organic matter decomposition are carried out through enzymatic digestion, enrichment by nitrogen excrement and transport of organic and inorganic materials (Sinha *et al.*, 2009).

During vermicomposting, earthworms maintain aerobic condition in the waste pile through burrowing, inverting and biochemical processes enhanced by microbial decomposition of substrate in the earthworm intestine (Suthar and Singh, 2008). Microbes convert major plant nutrients like nitrogen, potassium, phosphorus etc. present in the substrate into more soluble forms that are much more available to plants than those in the parent substrate (Sharma *et al.,* 2005). Earthworms and microbes, therefore, maintain a mutual positive effect. Where earthworms are present, there are more active bacteria and fungi, contributing in releasing nutrients from organic matter and making them available to plants (Kale and Karmegam, 2010).

2. 5.2. Physicochemical characteristics of vermicompost and vermiwash

2.5.2.1. Vermicompost

Vermicompost is a peat like material containing most nutrients in plant available forms such as nitrates, phosphates, calcium, potassium, and magnesium. Its macro and micro soil nutrients, plant growth regulators and other plant growth influencing materials such as auxins, cytokinins and humic substances produced by microbes make vermicompost preferable to other compost and plant nutrient sources (Pathma and Sakthive, 2012). Significantly, vermicompost can be considered an excellent product of homogeneous and odorless nature with reduced levels of contaminants, rich in microbial population and holds more nutrients over a longer period without adversely impacting the environment (Sharma *et al.,* 2005). It also adds humus to the soil, improves soil condition and plant growth while reducing the runoff and pollution (Lazcano and Dominguez, 2010).

2.5.2.2. Vermiwash

Vermiwash is a liquid leachate which can be collected by two ways. It can be collected by allowing excess water from the actively vermicomposting substrate in such a way that the water washes the nutrients from the vermicompost and the earthworm's body surface. The other method allows to collect vermiwash from the body cavity of earthworms without causing any harm to them (Suthar, 2010; Rameshguru *et al.,* 2011). In this method of collecting the fluid, sufficient amount of earthworms can be placed on petri plate preferably holding the plate in a slanting position and keeping earthworms pointing downwards. The vermiwash released due to warm water drips and gets collected at the lower side of the petri plate. Vermiwash contains high level of macro and micro nutrients like Ca, K, S, P, organic carbon, Fe, Mn, Cu and Zn (Hatti *et al*., 2010), nitrogen-fixing bacteria like Azotobactrer species (Agrobacterium and Rhizobium species) and some phosphate solublizing bacteria, enzymes, and hormones (Sinha *et al.,* 2010).

2.5.3. Environmental benefits of vermicomposting

Vermicomposting is self-improved low or no-energy-requiring zero-waste technology which is easy to operate and maintain (Sinha *et al.,* 2009). It creates a toxic free environment in various ways: it removes chemical contaminants from soils and reduces soil salinity while improving the soil bio-physicochemical properties. Inherently, earthworms bio-transform and biodegrade chemical contaminants in to a harmless and useful product, which reduce green house gas (GHG) emission (Sinha *et al.,* 2010). It promotes plant growth and increases yield 5-7 times as much fertilizer could and, can decrease the GHG emissions proportionately. Moreover, vermicompost increases 'biological resistance' in plants and protect them against pests and diseases either by repelling or by suppressing them. This is perhaps due to the presence of fungus (Actinomycetes) in large amounts in vermicompost (Sinha *et al.*, 2009).

2.5.4. Effect of vermicompost and vermiwash on soil physicochemical property

Application of vermicompost on soil has multiple benefits to soil, improves its natural fertility, and provides high surface area for microbial activity and for the retention of soil nutrients (Lazcano and Dominguez, 2010). It decreases the use of chemical fertilizers thereby reducing soil and water pollution, helps in restoring soil microbial population for nitrogen fixation and phosphate solubilization and, thus enhances crop yield (Sinha *et al.,* 2010). Vermicompost retains nutrients for long time better than conventional compost can deliver the required amount of macro and micronutrients including the vital NPK to plants in shorter time (Sinha *et al.*, 2009; Misra *et al.,* 2003). Therefore, soil enriched with vermicompost contains extra substances including plant growth hormones and humic acid that are scanty in chemical fertilizers (Lazcano and Dominguez, 2010). Vermiwash can be applied in various ways: foliar spray, soil and root application (Hatti *et al.,* 2010). Increased application rate of vermiwash increases plant growth and yield by enhancing the soil organic carbon contents and increasing beneficial soil microbial populations (Pathma and Sakthive, 2012).

2.5.5. Effect of vermicompost and vermiwash on seed germination and seedling growth

Seeds and seedlings determine the survival and reproductive capacity of plants and, therefore, have a critical position in the life history of plants. Commencement of seed germination depends mainly on the presence of favourable environmental conditions, such sufficient water, optimum temperature and adequate oxygen (Kermode, 2004). However, speedy seed germination process requires various seed treatments, such as soaking in water or aqueous solutions and scarification. Vermicompost showed to be adequate substrate for plant growth. It can substitute commercial fertilizers for vegetative growth probably due to high mineral N availability (Atiyeh *et al.,* 2000). Its addition to soil can improve plant morphology (Lazcano *et al.,* 2010). Vermiwash, a biological product enriched with beneficial microbes, enzymes and hormone enhances both seed germination and seedling growth, compared to water soaking treatment (Shakila and Rajeswari, 2008). Sinha *et al.* (2009) have suggested

vermiwash to be an excellent ecologically safe and cost-effective bioresource of plant nutrient/growth promoter for sustainable plant production at eco-friendly basis.

2.6. Effective Microorganism (EM) Technology in Agricultural Waste Management

Effective microorganisms (EM) were discovered and developed by a Japanese Agronomist, Teruo Higa, in Japan (Higa and Wididana, 1991; Higa and Parr, 1994). EM includes lactic acid bacteria, photosynthetic bacteria, and yeasts and mutually compatible with one another and can coexist in liquid culture (Higa and Parr, 1994). The basis for using EM species in various applications, including waste management, is attributed to the presence of lactic acid bacteria. They secrete organic acids, enzymes and antioxidants and contain strong sterilizing compounds powerful to suppress pathogens while enhancing organic matter decomposition (Sekeran *et al.*, 2005). EM are cultured and produced under anaerobic fermentation, and can break down compost materials into useable nitrogen-rich product in less than four weeks (Freitag, 2000). Composting feed stock are attributed to the activity of beneficial organisms in EM by converting the waste in to carbon dioxide (CO_2), methane (CH_4) or its use for growth and reproduction (Misra *et al.,* 2003).

2.7 Conventional compost

There are many approaches of conventional compost preparations. Pit composting is among others. The composting materials are required to be spread evenly in the pit in layers of 10-15 cm. On each layer is spread slurry made with 4.5 kg dung, 3.5 kg urine-earth and 4.5 kg of inoculum taken from a 15 day-old composting pit (Misra *et al.,* 2003). Sufficient quantity of water is sprinkled over the material in the pit to wet it. The pit is filled in this way, layer by layer, and it should not take longer than one week to fill (Moon, 1997; Misra *et al.,* 2003). Care should be taken to avoid compacting the material in any way. The composting material requires periodic turning. the first time 15 days after filling the pit, the second after another 15 days and the third after another month. At each turning, the material is mixed thoroughly, moistened with water and replaced in the pit (Misra *et al.,* 2003).

2.8 Ecological Requirement of Moringa stenopetala (Baker f.) and its benefits

Moringa stenopetala belongs to the Moringaceae family. *M.oleifera* (Lam.) and *M.stenopetala (*Baker f.) are the most widely cultivated species (Fahey, 2005). *M.stenopetala*, a deciduous plant native to Ethiopia, Northern Kenya and Eastern Somali, is the most economically important species after *M.oleifera* (Olson and Carlquist, 2001; Tenaye *et al.,* 2009). It is one of the world's most useful fast-growing trees grown throughout the tropics for human food, livestock forage, medicine, dye, and water purification (Palada and Chang, 2003). Basically, *M.stenopetala is* a tropical crop which grows best between 25 to 35^{o}C. It is a drought-tolerant tree which can grow well in areas receiving annual rainfall between 250 to 1500 mm. It can grow in altitudes up to 1200 m.a.s.l in the tropics. It prefers a well drained sandy loam or loamy soils. However, it will tolerate a soil pH range of 5.0–9.0 but does not grow in prolonged flooding or poorly drained clay soils (Palada and Chang, 2003; Amalgo, 2006). In Ethiopia specifically in the Rift Valley of southern Ethiopia, where it is widely cultivated, is locally known as *'aleko*' (Welayitato) or '*shiferaw'* (Amharic) among local communities (Andinet *et al.*, 2010). It is traditionally managed as backyard tree or hedge for its leaves used domestically due to its extraordinary nutritional and medicinal properties. It is a promising food source since the tree is full of leaves and exceptionally nutritious (Joshi and Mehta, 2010). It has long been known in folk medicine as having value in treating a wide variety of ailments (Fahey, 2005). It is known to be anti-helminthic, antibiotic, detoxifier, immune builder and has been used to treat malaria (Walter *et al.,* 2011).

It is a contingency crop in frequently drought-affected lowland areas with its high yielding capacity under drought condition and year round harvest. It plays a significant role in household food security. About 20-50 *M.stenopetala* trees are suggested to be enough to support a family with 10-15 members by providing food supply even in situations where no other food sources are available. Farmers in Ethiopia (Arbaminch and Konso environs) dominantly cultivate and use *M.stenopetala* leaf during both dry and wet seasons in their diet as it plays a vital role for household food security, as source of income, medicine, fodder, fuel and shade tree all year round (Tenaye *et al.,* 2009). Amaglo (2006) has suggested that its cultivation to be a viable economic venture to meet the growing demand for *M.stenopetala*

leaf products. Its leaves have distinctive strong and mustard like taste, contain calcium, iron and other trace minerals, and are eaten as a supplement to the major staple foods.

Propagation and management of Moringa stenopetala (Baker f.)

Propagation of *M.stenopetala* can be either through seed or cutting. The most common propagation method of the species in Ethiopia is direct seed sowing without seed pretreatment at temperature ranges between 20-30^{O}C (Price, 2007). The germination speed of untreated seeds depends on temperature, humidity and watering (Demel, 1995). *M.stenopetala* seedling requires soil with good water-holding capacity and good drainage (Palada and Chang, 2003; Price, 2007). *M.stenopetala* is suitable for more intensive production. In mostly subsistent farms it grows well as an intercrop in association with other crops, producing a significant amount of leaves (Price, 2007). This is the case justified in Konso traditional multi-crop farming system where it is well-suited for use in alley cropping systems (Tenaye *et al*., 2009).

2.9 Ecological Requirement of Jatropha curcas (L.) and its Benefits

Jatropha curcas (L.) is often locally referred to as 'Jatropha' or physic nut (English) (Jongschaap *et al.,* 2007). It is native to Central America and widely distributed in Africa and Asia. It is a tall bush/ shrub or small tree that can grow up to 6 meters tall. It belongs to the Euphorbiaceae family. Its lifespan is in the range of 50 years. It adapts to marginal soils with low nutrient content under severe drought environment. It, therefore, posses no fear to compete on agricultural lands used for food production. Its water requirement is extremely low and it can withstand long periods of drought by shedding most of its leaves to reduce transpiration loss (Jongh and Putten, 2010). It grows well in tropical and sub tropical regions of lower altitudes between 0-500 m.a.s.l. The optimum rainfall for *J.curcas* seed production is considered between 1,000 and 1,500 mm. The optimum temperature for *J.curcas* is between 20˚C and 28˚C and soil pH lies between 6.0 -8.5 within depth of 45cm. Aerated sand and loam are preferred soils (Jongschaap *et al.*, 2007; Jongh and Putten, 2010)

Drought, poor agronomic and silvicultural practices and non availability of quality planting material are among the major production constraints of *J.curcas* (Krishna *et al*., 2008). Growing a productive *J.curcas* crop requires correct fertilization and adequate rainfall or irrigation. Sufficient amounts of nutrient addition improve its seedling growth into a full size plant with good plant architecture (roots, stems, and leaves) and produce quality seeds (Grass, 2009; Jongh and Putten, 2010). Applications of fertilizer, according to Suriharn *et al.* (2011), increased branch number and plant height of a three-year old *J.curcas* and consequently improved its yield at a rate of 312.5 kg ha^{-1}. Therefore, *J.curcas* responds positively to a high organic matter level although it is often described as having a low nutrient requirement as it is adapted to poor soils (Jongh and Putten, 2010). It is a promising crop with many applications. It has a potential to reclaim problematic lands and restore eroded areas. Its cattle deterring characteristics protects other valuable food or cash crops. The seeds are toxic, non-edible, medicinal, and useful soap-making ingredient. Current interest by investors, farmers and non-governmental organizations in it is mainly due to its potential as a bio- energy crop. Seeds can be pressed for the production of bio-diesel, and the pressed residue of the seeds (press cake) can also be used for fertilizer and biogas production (Jongh and Putten, 2010).

Propagation and management of Jatropha curcas (L.)

Propagation methods of *J.curcas* can be seed, by stem cutting, grafting, budding, air layering or by clone. Seeds can be sown directly in either nursery beds or poly bags directly under shade. The bags should be long enough to avoid restricting taproot growth. Brittaine and Lutaladio (2010) have reported that pre-soaking in cow dung slurry for 12 hours gave 96 % germination compared to soaking in cold water or nicking the seed coat, which gave around 72 %. *J.curcas* seed germinates in any soil with a well watered and aerated (6–15 days) condition about not in waterlogged soils as the seeds will rot.

Response of Moringa stenopetala (Baker f.) and Jatropha curcas (L.) to Fertilizer Management

Although there is no clearly stated fertilizer recommendation for *M.stenopetala,* compost or well decomposed farmyard manure at a rate of 1–2 kg/tree can be applied at planting time at about 10–20 cm from the base to maintain productivity at an appreciably high level (Amalgo, 2006; Price, 2007). Moreover, earlier reports show that fertilizer management of *J.curcas* improved plant growth and productivity (Suriharn *et al.*, 2011). Application of NPK fertilizer (60 kg N and 30 kg P_2O_5 ha^{-1}) at planting and a year after increased plant height by 23 and 17%, and plant canopy by 31 and 24%, respectively, and significantly increased total dry matter accumulation with increasing level of seed yield of 518.5 kg ha^{-1}, which was 163.5% higher over absolute control treatment (Islam *et al.*, 2011).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine in a lath house. Jimma is geographically located at 346 km Southwest of Addis Ababa in Oromia Regional State at an elevation of 1710 meter above sea level and at latitude of 7^0 42' 9''N and 36^0 47' 6'' E longitude in Ethiopia. Jimma town receives an average total annual rainfall of 1500 mm with mean maximum and minimum temperatures of 26.8^0C and 13.6^0C, respectively (BPEDORS, 2000).

3.2 Material Collection

3.2.1. Collection of experimental materials

Seeds of *M.stenopetala* were collected from Ethiopian Institute of Agricultural Research (EIAR), Forestry Research Center (FRC), Addis Ababa, Ethiopia. While, *J.curcas* seeds were collected from Alamata Wereda office of Agriculture, Tigray, Ethiopia. Fresh undamaged *M.stenopetala* seeds were decocted before sowing. Coffee husk was collected from coffee processing plants around Jimma town. Earth worms were collected from JUCAVM soil laboratory which initially were introduced from Canada. EM was purchased from commercial supplier, Woljeejii Agricultural Industries Plc., Bishoftu, Ethiopia.

3.2.2. Vermicompost preparation and management

Prior to vermicomposting, air dried coffee husk was partially composted thermophilically for three weeks. Pre-decomposition was made in soil pit size of 1mx1mx1m wrapped with plastic sheet in order to favor the activity of anaerobic bacteria due to which temperature will rise up to 60^0C. Moreover, thermo-composting also helps to reduce pathogen populations, promotes microbial population, mass reduction, moisture management and softening of the substrate

(Pathma and Sakthive, 2012). Then, the partially composted coffee husk was placed in a plastic circular pot with 20 Liters size at room temperature. The vermicomposting pot was pierced with sufficient holes to allow optimum air on upper, bottom and sideways according to methods described by Suthar (2007). Supervision against predators and periodic management of covering with paper sheet layer, watering and turning was made for better vermicomposting performance of earth worms. The composting process was kept for about ninety days.

3.2.3 Compost preparation with EM and management

Activated EM and chlorine free water at a ratio of 1:18 (v/v) per kg of sun dried coffee husk substrate were mixed and prepared in a 1mx1mx0.5m pit wrapped with water proof plastic sheet under shade. Sufficient amount of sun dried coffee husk was mixed with fresh chopped Desmodium species (as bulking agent) at 70:30 (v/v). The composting materials were put in an air proof plastic sheet, mixed thoroughly and spread uniformly at about 5cm layer with sufficient moisture sprayed with watering cane till it became sticky on hand. The air proof plastic sheet encourages anaerobic composting. The layers were maintained porous enough that can allow microorganism movement but avoids free air movement in the early composting stages. After two weeks, weekly manual turning and tap water sprinkling was administered so as to facilitate the microbial decomposition (Misra *et al.,* 2003). The composting process was kept for about fifty one days.

3.2.4 Conventional compost preparation

A soil pit size of 1mx1mx0.5m pit wrapped with water proof plastic sheet under tree shade was used for composting. Sufficient amount of dried coffee husk was spread evenly in the pit in layers of 5cm. On each layer sufficient quantity of water was sprinkled over the material in the pit. Care was taken to avoid material compaction. The compost pile was turned weekly during the whole period of composting. At each turning, the material was mixed thoroughly,

moistened with watering can as described by Misra *et al.* (2003). The composting process was kept for about four months.

3.2.5 Vermiwash preparation

A handful of *Eisenia fetida* earth worms which fed coffee husk were immersed in 100 ml warm water and kept for 30 minutes on a 10cm diameter petri plate holding in a slanting position and keeping earthworms pointing downwards as described by Suthar (2010) and Rameshguru *et al.* (2011). The vermiwash was collected from the body cavity of earthworms at the lower side of the petri plate without causing any harm to them. Secreted enzyme containing extract was centrifuged to remove the insoluble materials at 3000 rpm for 10 minutes. The filtrate was made cell free using 0.2µ membrane filtration.

3.2.6 Physical and chemical analysis of vermicompost, EM compost and compost soil mixture before planting

A homogenized sample representing each soil-compost (coffee husk vermicompost, coffee husk EM compost and coffee husk conventional compost) mixture replicated three times was taken for lab analyses. The soil-compost mixture were analyzed for pH, organic carbon (OC), organic matter (OM), electrical conductivity (EC), total nitrogen (N), available phosphorus (AP), and exchangeable potassium (K). The pH and EC of samples were recorded by a digital pH meter and conductivity meter, respectively. The OC and OM of the samples were measured by Walkey-Black method (Walkley and Black, 1934); the TN was estimated by the Kjeldahl method (Jackson, 1973), and the AP contents of the samples were measured by Olsen method (Olsen *et al.*, 1954), and the Exchangeable K by flame photometric method (Simard, 1993), respectively.

3.2.7. Experiment 1: Effect of different coffee husk composts on seedling growth of *Moringa stenopetala* (Baker f.) and *Jatropha curcas* (L.)

3.2.7.1. Treatments and experimental design

The experiment consisted of three factors namely, species with two levels (*M.stenopetala* and *J.curcas*), coffee husk compost with three levels (vermicompost, EM compost, conventional compost) and coffee husk compost to top soil ratio (v/v) with five levels (0, 10, 20, 30, 40 %) (Appendix 1). Therefore, the treatments were arranged in 2 x 3 x 5 Factorial Randomized Complete Block Design (RCBD) with three replications. Fifteen pots per treatment per replication were maintained. All management practices, such as weeding and watering were done as per the general recommendations for tree nursery.

3.2.8. Experiment 2: Effect of coffee husk vermiwash on seed germination and seedling growth of *Moringa stenopetala* (Baker f.) and *Jatropha curcas* (L.)

3.8.8.1. Treatments and experimental design

The experiment consisted of two factors namely, species with two levels (*M.stenopetala* and *J.curcas*) and coffee husk vermiwash rate with five levels (0, 10, 20, 30, 40 % (v/v)) (Appendix 1). The basic soil used was top soil. Therefore, the treatments were arranged in 2 x 5 Factorial in Randomized Complete Block Design (RCBD) with three replications. Fifteen pots per treatment per replication were maintained. All management practices, such as weeding and watering were done as per the general recommendations for tree nursery.

3.2.9. Sowing *Moringa stenopetala* (Baker f.) and *Jatropha curcas* (L.) seed under lath house condition

Pure, defect less and large size seeds were used for the experiment after checking through water floating method to avoid light weighted seeds. Seeds of *M.stenopetala* were decocted for easy germination and to avoid decaying. Prior to sowing qualified seeds were soaked for about six hours to speed up germination. About two seeds from each species were sown independently according to the treatment code on their respective pot at about 2cm depth under lath house condition. The pots were mulched and watered immediately after sowing. Pots were watered twice every day till the final emergence with watering cane. After seedling emergence; seedlings were wedded and watered to the field capacity for about 60 days i.e the experiment was conducted during March 01- April 30, 2012.

3.2.10. Data collected

The following seedling growth parameters were collected 60 days after seed emergence from March 01 to April 30, 2012: leaf chlorophyll a and b (μ/ml), plant height (cm), stem diameter (mm), number of leaves, root length (cm), shoot fresh and dry weight (g), and root fresh and dry biomass (g). Leaf chlorophyll a and b were estimated following the procedure described in Baskaran *et al*. (2009). Five hundred mg of fresh leaf (FW) material was taken and ground with the help of pestle and mortar with 10 ml of 80% acetone. The homogenate was centrifuged at 800 rpm for 15 minutes. The supernatant was filtered and utilized for chlorophyll estimation. Absorbance was read at 645, and 663nm in the UV-spectrophotometer (U V-4000, Germany).

Chlorophyll ‘a’ (mg g^{-1} FW) = (0.0127) × (OD 663) – (0.00269) × (OD 645)
Chlorophyll ‘b’ (mg g^{-1} FW) = (0.0229) × (OD 645) – (0.00468) × (OD 663)

The numbers of leaves per plant were counted above the cotyledon scar (for *M.stenopetala*) while in the case of *J.curcas* leaves were counted excluding the cotyledon leaves. Plant height

was measured from shoot tip of the plant to the root collar; while stem diameter was measured immediately 1cm above the root collar with venire calipers perpendicularly as described by Peterson and Graves (2009). Root length was measured from the tip of the root collar to the tip of the longest root. Consequently, seedlings were clipped off and separated in to root and shoot parts. For analysis, average values of samples of 10 plants per plot of plant height , stem diameter, number of leaves, root length, shoot and root fresh weight were assessed. Whereas, shoot and root dry matter were recorded after oven drying at 60ºC to a constant weight independently per plot bases.

3.2.11 Data analysis

The data were checked for all the assumptions of ANOVA and subjected to Analysis of Variance (ANOVA) and correlation using SAS version 9.2 (SAS Institute Inc., 2010). Least Significant difference (LSD) test at 5% level of significance was employed for mean separation using SAS and MSTAT version 11 (Stata Corp., 2009). All the figures and tables were generated using Excel computer program. The general linear model used for analyses of variance is shown in equation 1 and 2 below, respectively for the experiment on the 'effect of coffee husk composts and coffee husk vermiwash on seedling growth of *M.stenopetala* and *J.curcas*.

$$Yijkl = \mu + \rho i + Aj + Bk + Cl + (AB)jk + (AC)jl + (BC)kl + (ABC)jkl + \epsilon ijkl \ldots\ldots(1)$$

Where,

$Y_{ijkl=}$ the response measures for the ijklth observation

μ = the overall mean effect

ρ_i = the effect of the ith block

A_j = the effect of the jth level of species j = 1-2

B_k = the effect of the kth level of coffee husk compost types k= 1-3

C_l = the effect of the lth level of coffee husk compost rate levels l= 0-4

$(AB)_{jk}$ = the effect of the interaction between species and coffee husk compost types

$(AC)_{jl}$ = the effect of the interaction between species and coffee husk compost rate

$(BC)_{kl}$ = the effect of the interaction between coffee husk compost and coffee husk compost rate

$(ABC)_{jkl}$ = the effect of interaction among species, coffee husk compost types and coffee husk compost rate

$Є_{ijkl=}$ the random error computed for the whole factor

$$Yijk = \mu + \rho i + Aj + Bk + (AB)jk + Єijk \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:

Y_{ijk} = the response measures for the ijklth observation

μ= the over all mean of all observations

$\rho_{i=}$ the effect of the ith block

A_j = the jth level of species factor j= level 1-2

B_k = the effect of the kth level of coffee husk vermiwash rate k= level 0-4

$(AB)_{jk}$ = the effect of the interaction between species and coffee husk vermiwash rate level

Єijk= the random error computed with the unit of the jth and kth observation in the ith block

4. RESULTS AND DISCUSSION

This particular study was conducted to evaluate the suitability of coffee husk compost (vermicompost, EM compost and conventional compost), and coffee husk vermiwash for seedling growth using *M.stenpetala* and *J.curcas* as testing crops. Data pertaining to the different seedling growth responses were collected, analyzed and the results were presented and discussed in a logical order in this particular chapter.

4.1 Soil Chemical Composition before Planting

Application of coffee husk compost types (vermicompost, EM compost, and conventional compost) and their respective rate considered in this particular study improved the physicochemical parameters (pH, EC(dS/m), %OC, %OM, %TN, AP(ppm), and exchangeable potassium (K) values of the soil mixture compared to the control (without compost) (Table 1 and Appendix 1).

Table 1: The interaction effect of coffee husk composts and rate of application on physical and chemical properties of the soil mixture before planting

Coffee husk compost types	Rate %(v/v)	pH	EC(dS/m)	%OC	%OM	%TN	Available P(ppm)	Exchangeable K (meq/100g)
Vc	0	5.26^{k}	0.27^{i}	4.16^{g}	10.11^{f}	0.46^{j}	6.25^{k}	1.25^{k}
Vc	10	6.85^{e}	0.44^{g}	7.18^{f}	15.57^{e}	0.71^{i}	11.69^{i}	2.34^{i}
Vc	20	7.45^{d}	0.84^{e}	9.35^{de}	24.45^{c}	1.25^{e}	44.92^{f}	8.98^{f}
Vc	30	8.32^{b}	0.98^{d}	11.20^{d}	31.45^{b}	1.53^{c}	68.98^{d}	13.80^{d}
Vc	40	8.63^{a}	1.25^{b}	17.11^{b}	40.50^{a}	2.05^{a}	111.30^{a}	22.25^{a}
Emc	0	5.27^{k}	0.17^{j}	4.18^{g}	10.10^{f}	0.46^{j}	6.20^{k}	1.24^{k}
Emc	10	5.82^{j}	0.29^{i}	8.28^{ef}	14.25^{e}	0.80^{h}	8.69^{j}	1.74^{j}
Emc	20	5.92^{i}	0.39^{gh}	14.42^{c}	16.04^{e}	0.96^{g}	38.84^{g}	7.77^{g}
Emc	30	6.53^{g}	0.55^{f}	15.49^{bc}	19.25^{d}	1.16^{f}	55.66^{e}	11.13^{e}
Emc	40	6.85^{e}	0.88^{e}	22.21^{a}	19.96^{d}	1.52^{c}	96.09^{b}	19.22^{b}
Cc	0	5.26^{k}	0.17^{j}	4.62^{g}	10.14^{f}	0.46^{j}	6.19^{k}	1.24^{k}
Cc	10	6.10^{h}	0.37^{h}	8.34^{ef}	16.22^{e}	0.72^{i}	7.82^{jk}	1.56j^{k}
Cc	20	6.65^{f}	0.85^{e}	13.60^{c}	19.35^{d}	1.28^{e}	30.57^{h}	6.11^{h}
Cc	30	7.50^{d}	1.11^{c}	15.57^{bc}	25.25^{c}	1.46^{d}	44.56^{f}	8.91^{f}
Cc	40	8.06^{c}	1.36^{a}	23.89^{a}	31.95^{b}	1.68^{b}	84.89^{c}	16.98^{c}
CV (%)		0.55	6.16	1.62	3.24	2.41	2.94	2.94
LSD (5%)		0.06	0.07	2.08	2.94	0.04	2.00	0.40

Means within a column represented by same letter are not significantly different at P<0.05

The pH of soil mixture was significantly (P<0.0001) affected by the combination of coffee husk compost type and rate (Table 1). Accordingly, coffee husk vermicompost at 40 %(v/v) resulted in maximum pH value followed by same compost at 30% as compared to the control. This result is in agreement with Lazcano and Dominguez (2010) who reported that increasing doses of plant derived vermicompost significantly increased the pH of the soil media. The

increased pH due to increased vermicompost rate might be attributed to the inherent constituents of the coffee husk.

Likewise, there was significant (P<0.0001) interaction between type and rate of coffee husk compost with respect to the Electrical conductivity (EC) of potting soil mixture (Table 1). The highest EC was observed for coffee husk conventional compost at 40 %(v/v), followed by coffee husk vermicompost at the same rate as compared to the control (Table 1). The observed difference in terms of EC could probably be due to the fact that different composting systems might have resulted in different compost products. This result is in agreement with the findings of Civeira (2010), who reported that EC of a soil increased from 2.15 to 2.22(dS m^{-1}) in response to 0 (control), and 7 kg m^{-2} dose of municipal solid wastes, respectively. Also, Lazcano and Dominguez (2010) reported that increased proportions of vermicompost application from 0 to 25% significantly increased EC from 0.33+0.001 to 0.66 + 0.03. According to Pattnaik and Reedy (2010) the increased EC with the incorporation of vermicompost could be probably due to the degradation of organic matter releasing minerals such as exchangeable Ca, Mg, K, and P in the available forms in the form of cations in the vermicompost and compost.

The organic carbon (OC) of the potting soil mixture was significantly (P<0.0001) influenced by the interaction of coffee husk compost type and rate (Table 1). Accordingly, the maximum OC was registered for coffee husk conventional compost at 40 %(v/v), which is statistically similar with coffee husk EM compost at 40 %(v/v), followed by coffee husk vermicompost at 40%(v/v). The apparent discrepancy in the OC content between the different coffee husk composts and their rate could be attributed to the difference in the mineralization rate of the composting systems. The observed maximum OC for coffee husk conventional compost and coffee husk EM compost might be attributed to the lower mineralization process. The suitability, abundance and type of microorganisms in conventional composting systems require longer and slow decay of organic matter and compost maturation (Frederickson *et al*., 2006; Sinha *et al.,* 2010). The higher availability of OC in coffee husk EM compost might have resulted from antagonistic factors such as the presence of chlorine in water, and oxygen leakage in the early composting stage (Higa and Wididana, 1991; Higa and Parr, 1994) and

shade condition. Whereas, the higher rate of mineralization of organic matter and fast composting process due to earthworm action along with micro-organisms may result in loss of organic carbon in the form of CO_2 (Suthar and Singh, 2008; Pattnaik and Reedy, 2010) in the coffee husk vermicompost.

The analysis of variance revealed that there was significant ($P< 0.0001$) interaction effect between type and rate of coffee husk compost in terms of OM of the soil mixture (Table 1). Accordingly, the maximum OM was recorded for coffee husk vermicompost at 40 % followed by the same rate of coffee husk conventional and coffee husk vermicompost at 30 %. The observed difference in OM might be due to the compost physiochemical quality, quantity, maturity and soil property which in turn was attributed to composting system difference (Litterick *et al.,* 2003; Civeira, 2010) and enhanced contribution of earth worms (Suthar and Singh, 2008; Pattnaik and Reedy, 2010; Pathma and Natarajan, 2012). Earthworm participation in the composting process enhances natural biodegradation and decomposition of organic materials from 60 to 80% by promoting the growth of 'beneficial decomposer aerobic bacteria' in the waste biomass and significantly produces better, rich in key minerals and beneficial soil microbes (Sinha *et al.,* 2010). Therefore, an increased amount of matured compost incorporation to a soil increases the organic matter. However, longer and slow decay of organic matter and compost maturation in the conventional composting system might have resulted in low organic matter (Frederickson *et al*., 2006; Sinha *et al.,* 2010). Moreover, the low availability of OM in coffee husk EM compost might also be attributed to the early stage of composting process, system failure due to leakage of oxygen in to the composting system and contamination of chlorine (Higa and Wididana, 1991; Higa and Parr, 1994).

There was significant ($P< 0.0001$) interaction between coffee husk compost type and rate in terms of total nitrogen (TN) of potted soil mixture (Table 1). The maximum TN was recorded for coffee husk vermicompost at 40 % followed by the same rate of coffee husk conventional compost as compared to other treatment combinations. The increased availability of nitrogen in the presence of increased rate of vermicompost is in agreement with the findings of Lazcano and Dominguez (2010) who reported that the TN steadily increased from 0.75 ± 0.02 (without) to 1.51 ± 0.06 due to 25% vermicompost applications. Moreover, Azarmi *et al.*

(2008) have reported that increased vermicompost treatment from 0, to 15t ha-1 improved the availability of TN (%) to 0.13 compared to 0.07 in the control plot. The possible reason for increasing TN could be due to the presence of the microbes in the earth worm gut which enhances the mineralization rate of organic matter containing proteins and consequent conversion of ammonium-nitrogen into nitrate and further increase in rate of $NH4^{+}$ and loss of OC in the form of CO_2. In addition, earthworms can increase the nitrogen levels of a vermicompost as they add their nitrogenous excretory products, mucus, body fluid, enzymes, and their dead tissues (Atiyeh *et al,* 2002; Suthar, 2007).

Available phosphorus (AP) in the pot soil mixture was significantly ($P<0.0001$) influenced by the interaction of coffee husk compost type and rate of application (Table 1). Accordingly, the maximum AP of pot soil mixture was recorded due to incorporation of coffee husk vermicompost at a rate of 40 % followed by EM compost at the same rate. The current result is in agreement with the work of Hernandez *et al.* (2010) who have reported that vermicompost contains more AP (0.88) than ordinary compost (0.71%). Similarly, Azarmi *et al*. (2008) has reported agreed that increased vermicompost treatment from 0 to 15t ha^{-1} improved the availability of AP (ppm) to 18.733 compared to 5.59 in the control plot. Orozco *et al.* (1996) associated the availability of phosphorus from coffee pulp vermicompost to increased phosphatase enzymes level and to the stimulatory effect of microorganisms which makes *Eisenia fetida* better than the ordinary compost. The passage of organic matter through worm's gut results in P converted to more bioavailability forms to plants (Sinha *et al*. 2010). Moreover, according to Shafei *et al.* (2008), the photosynthetic bacteria in EM compost might be responsible for increased availability of P and other nutrients in the soil. According to He *et al*. (2010) and Kasthuri *et al*. (2011), the increased soil P (%) with increased incorporation of compost in to potting soil is attributed to the activities of phosphatase enzyme which is responsible for P mineralization.

The Exchangeable potassium (K) of the potting soil mixture was significantly ($P<0.0001$) influenced by the interaction of type and rate of coffee husk compost (Table 1). Accordingly, the maximum K was registered for coffee husk vermicompost at 40 % followed by the same rate of coffee husk conventional compost and coffee husk EM compost. The apparent

variation in the K content between the different coffee husk composts and their rate could be attributed to the difference in the mineralization rate of the composting systems. The observed maximum K with coffee husk vermicompost might be attributed to the higher mineralization process. The current result is in agreement with the findings of Azarmi *et al*. (2008) who reported that increased vermicompost treatment from 0 to 15t ha^{-1} increased the availability of K (ppm) to 599.67, compared to 379.00 for the control. The increased availability and recovery of K can be attributed to the selective feeding of earthworm on organically rich substances with enzymatic influence in worm's gut on finer soil particles (Pattnaik and Reddy, 2010). In general the lowest values of all soil chemical properties were observed for the control treatment (Table 1).

4.2. Effect of different Composts on the Growth Performances of *M.stenopetala* and *J.curcas* Seedlings

Application of coffee husk composts considerably increased leaf chlorophyll a and b ($P<0.0001$), plant height per plant ($P =0.0001$), leaf number per plant ($P<0.0001$), stem girth ($P=0.034$), shoot and root fresh weight ($P<0.0001$), root length ($P=0.0252$) and shoot and root dry weight ($P<0.005$) of *M.stenpetala* and *J.curcas* seedlings. Seedling growth of both species was improved, because coffee husk composts improved soil bio-physicochemical qualities, in addition to nutrient status of soil. This result is supported by the findings of Golabi *et al*. (2004), who reported that application of compost to the soil significantly contributed to plant growth and development due to its better nutrient content and ability to improve the soil physicochemical properties. The same authors have reported that increased application of compost from 0 to 120 t per acre improved soil quality, such as the soil N, P, K, bulk density, soil organic matter content, nutrient distribution and other soil quality parameters, which consequently improved maize crop yield from 2.7 to 6.4 metric t/ha, respectively.

4.2.1. Seedling leaf chlorophyll content

There was no significant interaction among species, compost type and rate for leaf chlorophyll a and chlorophyll b content. The two way interaction effect of compost type and rate, species types and rate were not significant (Appendix 4). Nevertheless, chlorophyll a, and b levels in the leaf were significantly influenced by the two way interaction of species and coffee husk compost type, respectively (Table 2 and Appendix 4). Hence, the maximum leaf chlorophyll a, and b was registered for *M.stenopetala* due to coffee husk vermicompost, which was statistically at par with conventional compost and EM compost, and for *J.curcas* treated with coffee husk vermicompost and EM compost (Table 2). The observed difference in chlorophyll content can be attributed to either the genetic difference or due to nutrient supply contribution.

The superior promotion effect of coffee husk vermicompost on leaf chlorophyll contents might be attributed to its organic matter, N and humic substances (Atiyeh *et al.,* 2002; Uwumarongie *et al.,* 2012). The Pearson Correlation Coefficients showed the presence of strong correlation between chlorophyll a and b with nitrogen (r=0.76, 0.76), available phosphorus (r=0.72, 0.75) and potassium (r=0.72, 0.75), respectively. Moreover, the improvement of chlorophyll due to coffee husk EM compost can possibly be attributed to the presence of N fixing and phospotase bacteria. In agreement with the results of the present study it has been reported that photosynthetic enzymes require nitrogen, which is often a limiting resource (Forseth, 2010). Similarly, it has been observed that chlorophyll content increased significantly with increase in K supply (Asgharipour and Heidari, 2011). Optimum availability of N, P, and K in the soil improves plants photosynthetic efficiency and simultaneously increases plant growth (Onanuga *et al.,* 2012).

Table 2: Seedling leaf chlorophyll content as influenced by the interaction effect of species and coffee husk compost type

Species	Compost types	Chlorophyll a(µ/ml)	Chlorophyll b(µ/ml)
M.stenopetala	Vermicompost	12.34[a]	4.24[a]
	EM compost	10.62[ab]	3.64[ab]
	Conventional compost	11.89[ab]	4.02[ab]
J.curcas	Vermicompost	10.28[ab]	3.59[ab]
	EM compost	10.37[ab]	4.02[ab]
	Conventional compost	9.02[b]	3.07[b]
CV		18.17	16.91
LSD (5%)		3.19	1.03

*Means within a column represented by same letter are not significantly different at P<0.*05

As shown in Figure 1 increased application rate of coffee husk compost significantly (P<0.0001) affected seedling leaf chlorophyll a and b (Appendix 4). Quesni *et al.* (2012) have also reported that chlorophyll a and b content in *Matthiola incana* (L.) leaf tended to increase by increasing the rate of Nile compost up to 200g/pot, compared to no compost treatment. The increase in chlorophyll amount due to coffee husk compost could possibly be due to humic substances (Atiyeh *et al.,* 2002), nutrients in available forms during mineralization and improved soil properties, which promote plant water use efficiency, and consequently, enhance photosynthesis (Thompson *et al.,* 2008; Mazhar *et al.,* 2011).

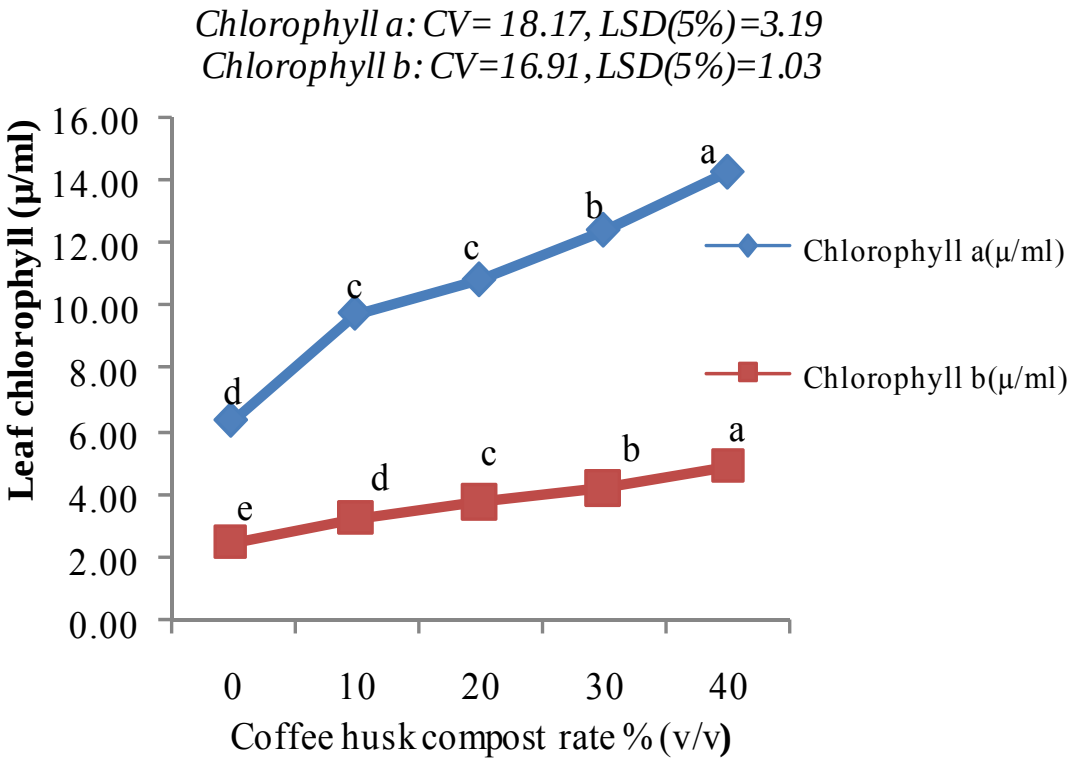

Figure 1. Seedling leaf chlorophyll content (µ/ml) as influenced by coffee husk compost rate. Means denoted by same letter within same line are not significantly different at P<0.05

4.2.2. Plant height

The analysis of variance for plant height at the end of 60 days showed absence of significant interaction among species type, compost type and compost rate, and between compost type and rate, species and compost types, and species types and compost rate (Appendix 5). However, effects of species (P=0.0001), compost type (P= 0.0003), and compost rate (P<0.0001) were significant (Table 3, 4, 5 and Appendix 5).

Maximum plant height was recorded for *M.stenopetala* (29.9cm) (Table 3). The observed difference in seedling plant height between the two species receiving the same treatment could probably be due to variations in their genetic make up. The longest seedling height was observed due to application of coffee husk conventional compost (30.14cm), followed by vermicompost (29.10cm) (Table 4). In contrast, EM compost (28.07cm) resulted in the

shortest plant height. The possible reason for the observed increase in plant height due to coffee husk conventional compost could be due to its positive contribution to increased surface water infiltration capacity, water holding capacity, improved root penetration of the seedlings (Thompson *et al.,* 2008) and increased availability of nutrients. The Pearson Correlation Coefficients showed the existence of good correlation between the pot soil mixture of EC, TN (r=0.69, 0.65), OM, TN, and K (r=0.59) and plant height growth. Increased availability of soil N and P improve plant height (Onanuga *et al.,* 2012).

However, the current result is in contrast with the findings of Bachman and Metzger (2008) who reported that vermicompost amended soil due to its hormone-like activity more enhanced plant growth and altered plant morphology as compared to conventional compost. Though literature pertaining growth performance of *J.curcas* and *M.stenopetala* at seedling stage is scarce, Kumara *et al.* (2009) have also reported that application of vermicompost to *J.curcas* significantly increased plant height by 25.13 and 17.53% over the control after 11 and 14 months of planting, respectively. As depicted in Table 5, coffee husk compost application to *M.stenopetala* and *J.curcas,* in different rate irrespective of compost type significantly ($P< 0.05$) contributed to seedling plant height. As a result, seedling plant height increased with increasing compost rate compared to the control. This result is in agreement with the work of Quesni *et al*. (2012) who observed increased *Matthiola incana* seedling height in response to elevated rate of Nile compost up to 200g/pot.

Table 3: Seedling growth attributes of *M.stenopetala* and *J.curcas* as influenced by species

Species	**PL (cm)**	**LN (n)**	**SG(mm)**	**SFW (g)**	**SDW(g)**	**RDW (g)**
M.stenopetala	28.29[b]	8.69[a]	7.60[a]	7.80[b]	1.12[b]	0.71[a]
J. curcas	29.92[a]	5.00[b]	5.60[b]	13.50[a]	1.70[a]	0.24[b]
CV (%)	6.40	4.46	10.21	8.64	15.81	1.31
LSD (5%)	0.79	0.13	0.28	0.39	0.09	0.03

Means within a column represented by same letter are not significantly different at P<0.05
PL = plant height, LN= leaf number, SG= stem girth, SFW= shoot fresh weight, SDW = shoot dry weight, RDW= root dry weight

Table 4: Seedling growth attributes of *M.stenopetala* and *J.curcas* as influenced by application of coffee husk compost types

Coffee husk compost types	PL (cm)	LN (n)	SG (mm)	SFW (g)	SDW (g)	RDW (g)
Vermicompost	29.10[b]	7.05[a]	6.83[a]	11.30[a]	1.53[a]	0.54[a]
EM compost	28.07[c]	6.68[c]	6.55[ab]	10.37[b]	1.32[b]	0.41[c]
Conventional compost	30.14[a]	6.81[b]	6.40[b]	10.29[b]	1.38b	0.47[b]
CV%	6.40	4.46	10.21	8.64	15.81	1.31
LSD (5%)	0.96	0.16	0.35	0.48	0.11	0.04

Means within a column represented by same letter are not significantly different at P<0.05

PL = plant height, LN= leaf number, SG= stem girth, SFW= shoot fresh weight, SDW = shoot dry weight, RDW= root dry weight

4.2.3. Leaf numbers

With regard to leaf number per seedling, the findings of the present study depicted that there was no significant interaction among species, compost type and compost rate. Besides, the interaction of compost type and compost rate, species type and compost rate, and species and compost type didn't significantly affect the number of leaves (Appendix 4). However, the main effects of species, compost type and compost rate were significant (P<0.0001) (Table 3, 4, 5 and Appendix 4) and *M.stenopetala* showed more leaf number than did *J.curcas.*

As shown in Table 4, coffee husk compost significantly (P<0.0001) affected leaf number per plant. Accordingly, vermicompost resulted in more leaf number per plant formation than did conventional and EM compost. Vermicompost enables plant to absorb nutrients (Ansari and Sukhraj, 2010; Ansari and Jaikishun, 2011). Moreover, the improved soil water holding capacity, fast delivery of plant growth hormones, enzymes and nutrients from vermicompost (Suthar, 2007, 2009, 2010; Sinha *et al.,* 2009 and 2011) might have favoured the production of more n umber of leaves and enhanced photosynthetic activity. Leaf number, leaf number significantly (P<0.0001) increased with increased coffee husk compost rate (Table 5). This

finding is similar with the work of Chamani *et al*. (2008) who reported that incorporation of 20-60% vermicompost per pot on *Petunia hybrida* seedling resulted in more total leaf number per plant than did the control treatment without compost amendment. Also, organic fertilizers may stimulate plant growth, nutrient absorption and activate many species of living organisms, which release plant hormones (Sinha *et al.,* 2009 and 2011; Suthar, 2007, 2009, 2010) when available in adequate amount.

Table 5: Effect of coffee husk compost rate on seedling plant height , leaf number, stem girth, shoot fresh and dry weight, and root dry weight of *M.stenopetala* and *J.curcas*

Parameters considered	**Rate %(v/v)**					**CV**	**LSD**
	0	**10**	**20**	**30**	**40**	**(%)**	**(5%)**
Plant height (cm)	26.92^{c}	27.05^{c}	29.38^{b}	30.49^{ab}	31.68^{a}	6.40	1.242
Leaf number (n)	6.40^{c}	6.58^{c}	6.81^{b}	7.14^{a}	7.30^{a}	4.46	0.204
Stem girth (mm)	6.17^{cd}	5.97^{d}	6.50^{bc}	6.94^{ab}	7.32^{a}	10.21	0.450
Shoot fresh weight (g)	9.31^{d}	9.54^{d}	10.52^{c}	11.61^{ab}	12.27^{a}	8.64	0.614
Shoot dry weight (g)	1.22^{c}	1.21^{c}	1.44^{b}	1.55^{ab}	1.62^{a}	15.81	0.150
Root dry weight(g)	0.42^{cd}	0.46^{bc}	0.51^{b}	0.60^{a}	0.39^{d}	1.31	0.054

Means within a row represented by same letter are not significantly different at P<0.05

4.2.4. Seedling stem girth

There was no significant three way interaction among species type, coffee husk compost type and coffee husk compost rate for seedling stem girth. Similarly, the interaction of species and compost type, species and compost rate, and compost type and compost rate also didn't significantly affect stem girth (Appendix 5). However, the effects of species (P<0.0001), compost type (P=0.034) and compost rate (P<0.0001) were significant (Table 3, 4, 5 and Appendix 4). Accordingly, thicker stem girth was observed for *M.stenopetala* than for *J.curcas* (Table 3). The apparent stem girth difference between the two species could be due to the nature of the two species tested. *M.stenopetala* is a tree 6-12 m tall with a trunk more or less 60 cm in diameter at breast height, strongly branched crown, thick at base and swollen

woody roots (Olson and Carlquist, 2001) compared to *J.curcas* which is a shrub about 6m high and nearly 20 cm in diameter. The well developed stem girth *of M.stenopetala* might help the plant as a strategy for water-storing and to allocate more nutrients as insurance against biotic and abiotic stress compared to *J.curcas.*

Vermicompost contributed to the formation of larger stem girth (6.83cm), which is statistically similar with coffee husk EM compost (6.55cm), followed by conventional compost (6.34) (Table 4). The observed increase in stem girth in response to vermicompost treatments could be attributed to the improved soil chemical and physical properties such as soil water holding capacity (Arisha *et al.,* 2003; Uwumarongie *et al.,* 2012) and plant growth promoting hormones (Suthar, 2007, 2009, 2010; Sinha *et al.,* 2009 and 2011).

As illustrated in Table 5, increased coffee husk compost rate significantly enhanced stem girth ($P<0.0001$). As a result, incorporation of coffee husk compost at 20, 30, and 40 % (v/v) improved seedling stem girth by 5.35, 12.48, and 18.64 percent, respectively over the unamended soil. The current result is in agreement with the findings of Richardson *et al*. (2009), who reported that *J.curcas* seedling girth growth gradually increased by increasing Nile compost rate (0, 100 and 200 g/pot) compared with unamended soil (control).

4.2.5. Seedling shoot fresh weight

Results of the present study showed non-significant interaction effects among species, compost types and compost rate, and species and compost rate for shoot fresh weight (Appendix 4). However, shoot fresh weight was significantly influenced by the interaction of species and coffee husk compost type ($P=0.0012$) (Table 6) and, species and coffee husk compost rate ($P<0.0001$) (Figure 2). Coffee husk vermicompost contributed the maximum shoot fresh weight for *J.curcas* followed by coffee husk EM compost for the same species which was statistically at par with coffee husk conventional compost. In contrast, the least shoot fresh weight was recorded from *M.stenopetala* grown in all coffee husk compost types. The observed difference in terms of shoot fresh weight due to coffee husk vermicompost application could probably be attributed to its EC (dS/m), %OM and TN content which might

have facilitated more water and nutrients absorption and assimilation in to plant biomass (Arisha *et al*., 2003).

Table 6 Interactive effects of plant species and coffee husk compost type on shoot fresh and dry weight (g) and root dry weight of *M.stenopetala* and *J.curcas*

Species	**Coffee husk compost types**	**SFW (g)**	**SDW (g)**	**RDW (g)**
M.stenopetala	Vermicompost	7.92^{c}	1.13^{c}	0.82^{a}
M.stenopetala	EM compost	7.80^{c}	1.10^{c}	0.60^{b}
M.stenopetala	Conventional compost	7.68^{c}	1.14^{c}	0.71^{ab}
J.curcas	Vermicompost	14.69^{a}	1.93^{a}	0.26^{c}
J.curcas	EM compost	12.93^{b}	1.54^{b}	0.23^{c}
J.curcas	Conventional compost	12.90^{b}	1.63^{ab}	0.23^{c}
CV (%)		8.64	15.81	1.31
LSD (5%)		1.50	0.37	0.14

Means within a column represented by same letter are not significantly different at P<0.05.
SFW= shoot fresh weight, SDW = shoot dry weight, RDW= root dry weight

Both species responded significantly (P<0.0001) to increased rate of coffee husk compost (Figure 2). Hence, the highest shoot fresh weight was observed for *J.curcas* at 40 and 30 %. While, *M.stenopetala* gave the least shoot fresh weight at 0 and 10 % compost rate. This result could be attributed to the fact that increased compost rate might have increased nutrient level, water holding capacity and favourable growth condition and thereby contributed to better seedling vegetative formation and consequently increased plant water status and weight gain. The present finding was in agreement with the works of Chamani *et al*. (2008), who have reported that seedling shoot fresh and dry weights of *Petunia hybrida* increased significantly in response to vermicompost incorporation at 20 and 40%, compared to the control treatment. The increased shoot fresh weight in *J.curcas* compared to *M.stenopetala* could be due to its larger leaf size, stem biomass holds more water in its tissue. Moreover, the increased coffee husk compost rate could probably increased nutrients and water up take by plant as a result of improved soil physiochemical properties (Arisha *et al*., 2003; Uwumarongie *et al.,* 2012).

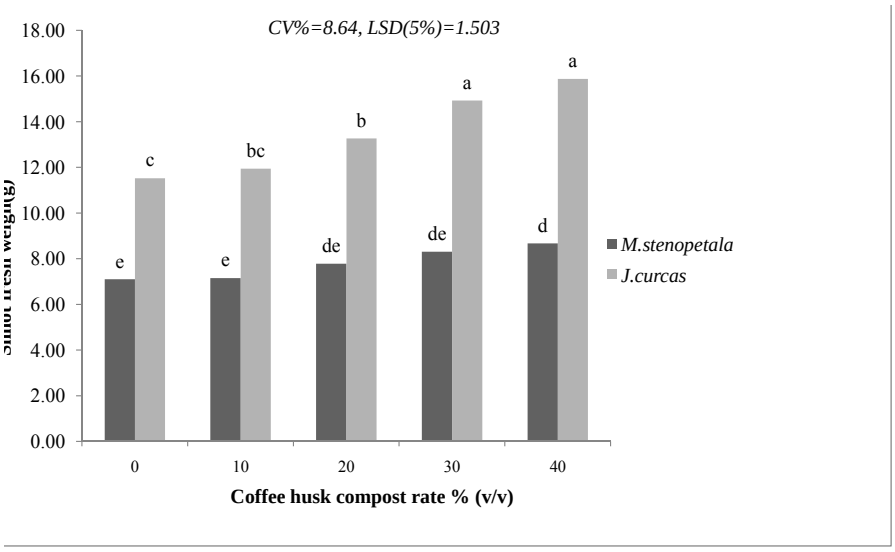

Figure 2: Seedling shoot fresh weight (g) of *M.stenopetala* and *J. curcas* as influenced by the coffee husk compost rate.

Bars caped by the same letter(s) are not significantly different at P< 0.05

4.2.6. Seedling shoot dry weight

Three way interactions of species, coffee husk compost type and coffee husk compost rate didn't affect seedling shoot dry weight. Likewise, the two way interaction of compost type and compost rate didn't brought about significant difference in shoot dry weight (Appendix 5). However, shoot dry weight, differed significantly (P=0.0051) due to the interaction effect of species and compost type (Table 6 and Appendix 4). Hence, maximum seedling shoot dry weight was observed for *J.curcas* grown in potting media amended with coffee husk vermicompost which was statistically similar to pots amended with coffee husk conventional compost followed by coffee husk EM compost for the same species. In contrast,

M.stenopetala showed the least seedling dry weight when supplemented with the three compost types used in this experiment. The observed difference among the seedling shoot dry weight with respect to coffee husk compost types (Table 6) could be attributed to seedling vegetative growth of the seedlings in response to the amount of mineral nutrients gained within plant biomass (Perner *et al.*, 2007) which in turn is a function of chlorophyll.

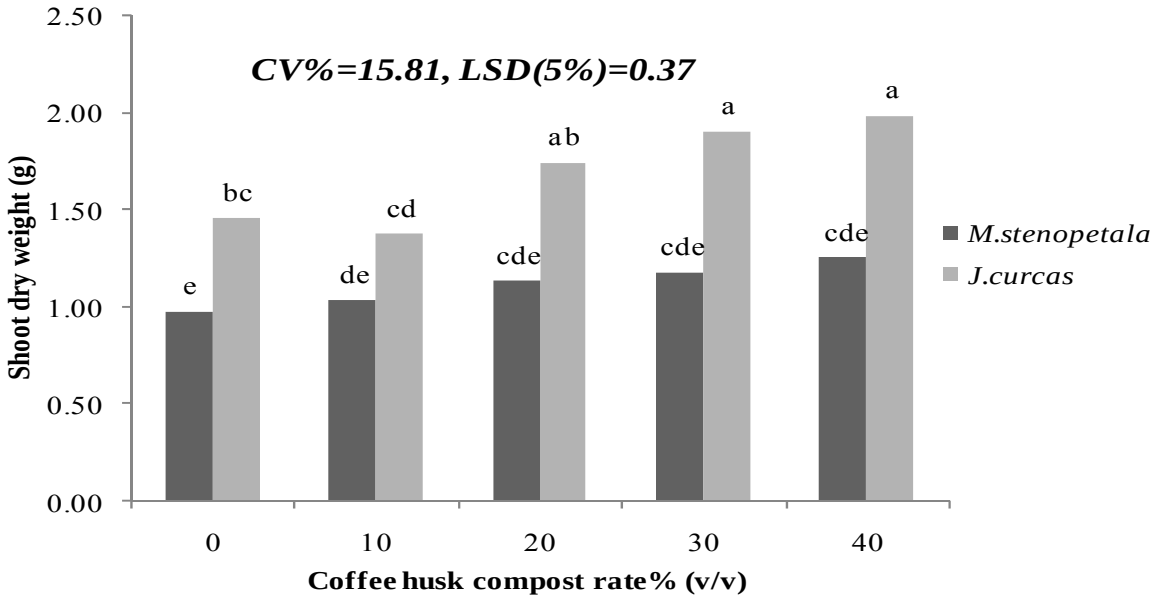

Figure 3: Seedling shoot dry weight (g) of *M.stenopetala* and *J. curcas* as influenced by coffee husk compost rate.
Bars caped by the same letter(s) are not significantly different at P< 0.05

The result presented in figure 3 depicts that the interaction effect of species and coffee husk compost rate treatments on the shoot dry weight (g/10plants) was significant (P=0.0471). Among the different compost rates, 30 and 40 % resulted in maximum seedling shoot dry weight. Accordingly, shoot dry weight increased by 30.85 and 36.41 in *J.curcas*, and 20.48 and 28.05 percent in *M.stenopetala*, for the 30 and 40% compost, respectively, compared to the control treatment. Conversely, the lowest seedling shoot dry weight was obtained due to 10% compost use in *M.stenopetala,* which was about 6.00 percent compared to the control (Figure 3). The increase in seedling shoot dry weight with increased application rate of coffee

husk compost might be due to expansion and formation of tissues accompanied by more allocation of mineral nutrients (Perner *et al.*, 2007) in to the seedling biomass. This finding also agrees with the works of Chamani *et al.* (2008), who reported that *Petunia hybrida* treated with 20 and 40% vermicompost significantly gained more fresh and dry weights compared to the unamended control. The increased shoot dry weight could be due to the improved soil physiochemical property which might have suited for better plant biomass accumulation (Arisha *et al*., 2003; Uwumarongie *et al.,* 2012).

4.2.7. Seedling root length

Seedling root length was significantly (P=0.0252) affected by the three way interaction of species, coffee husk compost type and coffee husk compost rate (Table 7 and Appendix 4). Accordingly, *J.curcas* seedlings had the maximum root length for coffee husk vermicompost at 40% which was at par with coffee husk EM compost at 30% and 40 % for the same species, and coffee husk vermicompost and coffee husk conventional compost at a rate of 40 % for *M.stenopetala* The apparent difference in root length among the compost types and their rate could be due to the difference in their nutrient contents, which could be attributed to variations in the composting process used (Suthar, 2007, 2009, 2010; Boraste *et al.,* 2009; Sinha *et al.,* 2009 and 2011). Mane and Smita (2012) have also reported that vermicompost improves the air-water relationship of soil which consequently increases the water retention capacity and encourages extensive development of plant root system. Moreover, the presence of a combination of nitrogen fixing bacteria, phototrophic bacteria, lactic acid bacteria and yeast (Boraste *et al.,* 2009) in EM compost positively influenced seedling root growth. The Pearson Correlation Coefficients showed the presence of positive correlation between TN (r=0.61), AP (r=0.67), and K (r=0.67) with seedling root length. N, P, and K are necessary in many plant functions including growth, protein synthesis, carbohydrate metabolism, photosynthesis, enzyme activation, osmotic regulation and efficient use of water, developing active, robust and healthy root systems (Forseth, 2010; Hodges, 2010; Onanuga *et al.,* 2012).

Table 7: Interactive effects of tree species, coffee husk compost type and rate of compost application on seedling root length (cm). .

Species	Rate	Coffee husk compost type		
		Vermicompost	**EM compost**	**Conventional compost**
M.stenopetala	0	10.79^{ghij}	9.68^{ij}	10.22^{hij}
	10	10.92^{gh}i	10.80^{ghij}	10.67^{ghij}
	20	11.58^{fgh}	10.93^{ghi}	11.75^{efg}
	30	12.67^{cdef}	11.82^{efg}	12.75^{cdef}
	40	13.30^{abcd}	12.68^{cdef}	13.43^{abc}
J.curcas	0	9.80^{4j}	9.58^{ij}	9.48^{j}
	10	10.67^{ghij}	11.70^{efg}	10.28^{hij}
	20	11.93^{defg}	12.60^{cde}f	11.39^{fgh}
	30	13.07^{bcde}	13.50^{abc}	11.88^{efg}
	40	14.63^{a}	14.37^{ab}	12.75^{cdef}
CV%			7.13	
LSD (5%)			1.37	

Means followed by the same letter(s) are not significantly different at P = 0.05

4.2.8. Seedling root fresh weight

The analysis of variance for root fresh weight revealed the presence of significant interaction (P=0.0003) among species, compost type, and compost rate (Table 8 and Appendix 4). Accordingly, *M.stenopetala* had the highest root fresh weight when treated with coffee husk vermicompost at a rate of 40%, followed by coffee husk conventional compost and EM compost applied at the same rate and vermicompost at 30 %. The improved performance of coffee husk vermicompost treatment at a higher rate (40%) might be due to its suitability for extensive plant root system development, which might have resulted from improved nutrient

supply, soil porosity, bulk density and high uptake of water (Arisha *et al.,* 2003; Adebayo *et al*., 2011; Mane and Smita, 2012; Uwumarongie *et al.,* 2012). The current result was in agreement with Lazcano *et al*. (2010), who reported that application of vermicompost at 25% dose increased root fresh weight of *Pinus pinaster* by 0.22(g) compared to the lower doses. According to Bachman and Metzger (2008) application of vermicompost to vegetables increased root fresh and dry weight because of its hormone-like activity for better root initiation and increased root biomass. Richardson *et al*. (2009) justified that water, growth hormone and nutrient availability might have influenced plant root morphology. Nutrient-rich environments and the presence of hormones like auxins enable plants to optimize the exploitation of the available resources which are in turn transformed into photoassimilates and transported again to the root consequently influencing plant growth (Mininni, C., 2012).

Table 8: Seedling root fresh weight (g) of *M.stenopetala* and *J.curcas* as influenced by the interaction of species, coffee husk compost type and rate

Species	Rate %(v/v)	Coffee husk compost type		
		Vermicompost	**EM compost**	**Conventional compost**
M.stenopetala	0	6.47^{j}	6.40^{j}	6.44^{j}
	10	7.51^{f}	6.81^{h}	6.62^{i}
	20	7.73^{e}	7.15^{g}	7.77^{de}
	30	8.24^{b}	7.85^{d}	8.15^{c}
	40	8.84^{a}	8.23^{bc}	8.28^{b}
J.curcas	0	0.92^{r}	0.93^{r}	0.95^{r}
	10	1.28^{o}	1.07^{q}	1.07^{q}
	20	1.49^{m}	1.10^{q}	1.07^{q}
	30	1.81^{l}	1.19^{q}	1.23^{op}
	40	2.51^{k}	1.27^{op}	1.37^{n}
CV (%)		1.31		
LSD (5%)		0.09		

Means followed by same letter(s) are not significantly different at P=0.05

4.2.9. Seedling root dry weight

Result of the present experiment showed that there was no significant interaction effect among species, coffee husk compost type and coffee husk compost rate; nor between coffee husk compost type and rate for seedling root dry weight (Appendix 4). However, the interaction effect of species and coffee husk compost type significantly ($P<0.0001$) influenced seedling root dry weight (Table 6 and Appendix 4). Accordingly, *M.stenopetala* had the highest root dry weight due to coffee husk vermicompost which had statistically the same effect as coffee husk conventional compost, followed by EM compost. In contrast, root dry weight of *J.curcas* has least values for all coffee husk compost type. The difference in root dry weight in response to coffee husk composts between the two species can be attributed to species differences and/or the suitability of materials and provision of minerals for the seedling growth, in addition to more biomass allocation to the root system. This result was in agreement with the findings of Bachman and Metzger (2008), who reported that vermicompost increased root fresh and dry weight in French marigold, pepper, tomato and cornflower because of its hormone-like activity for better root initiation and increased root biomass.

As illustrated in Figure 4, seedling root dry weight was significantly ($P=0.0047$) affected by the interaction between species and coffee husk compost rate. Hence, seedling root dry weight proportionally increased with increasing compost rate up to the level of 30 % but, declined then after in both *M.stenopetala* and J.curcas. This might be attributed to the fact excessive supply of nutrients beyond their biological requirement may cause growth retardation or total collapse due to possible toxic effect, which may be in this case attributed to excessive salt content of the coffee husk compost (Kasthuri *et al.,* 2011). This finding was also in agreement with the findings of Cuevas (2009), who reported that optimum shoot and root dry weights of *J.curcas* seedlings is improved proportionally to the amount of compost added not exceeding 16% (w/w) soil-to-compost ratio compared with those grown in pure soil.

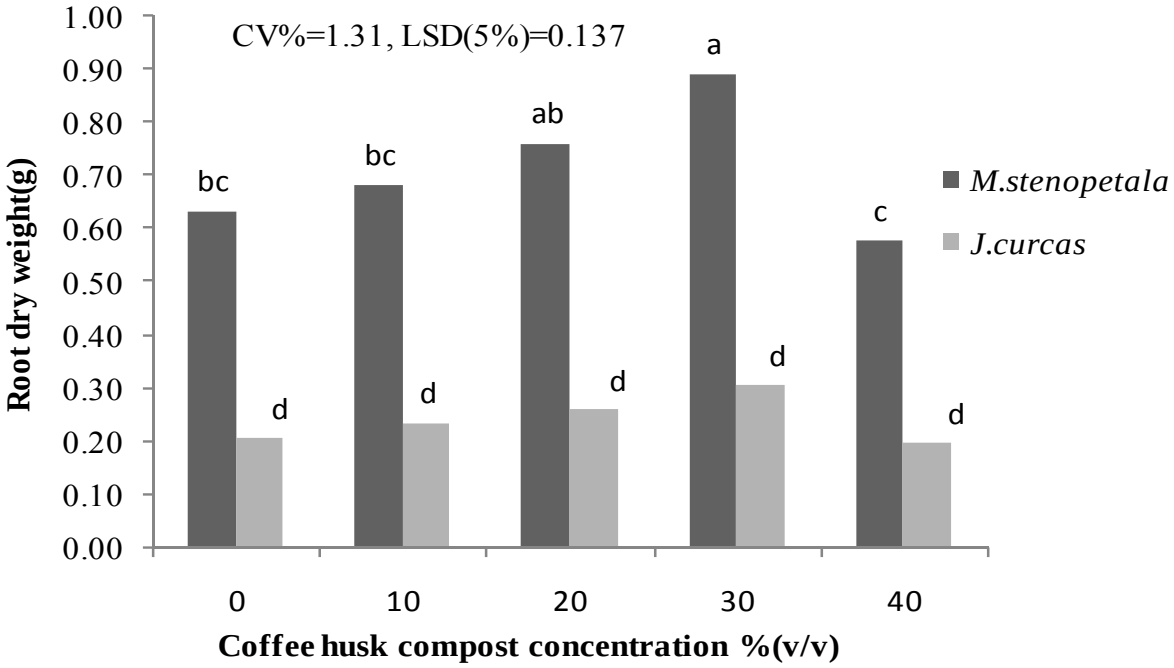

Figure 4: Seedling root dry weight (g) of *M.stenopetala* and *J. curcas* as influenced by coffee husk compost rate.
Bars caped with the same letter(s) are not significantly different at P< 0.05

Seedling root dry weight differed significantly (P<0.0001) due to the combined effect of coffee husk compost type and species (Table 6). The maximum root dry weight was recorded for *M.stenopetala* at 30% while the lowest was observed for *J.curcas* at 40% compost rate which was statistically at par with *J.curcas* at 0, 10, 20, and 30 %. The findings of Bachman and Metzger (2008) also indicate that increased vermicompost substitution because of its hormone-like activity improves root initiation and increased root biomass. Moreover, minerals from conventional compost type might have been better translocated in to the seedling root biomass.

4.3. Effect of Coffee husk Vermiwash on Seedling Growth of M.stenopetala and J.curcas

4.3.1. Leaf chlorophyll a and b content

There was no significant interaction among species and coffee husk vermiwash rate leaf chlorophyll a and b (Appendix 5). However, the two species showed significantly ($P<0.0001$) different chlorophyll a, and b content in their leaf (Table 9). Hence, levels of *M.stenopetala* seedlings contained more chlorophyll a and b than did *J.curcas* leaves owing to the inherent genetic botanical differences.

Seedling chlorophyll a was not significantly affected by coffee husk vermiwash rate. Nevertheless, chlorophyll b was significantly ($P<0.0001$) affected by increased coffee husk vermiwash rate (Appendix 5). The possible reason to the increased chlorophyll b synthesis due to increased vermiwash foliar spray rate could be owing to the earth worm derived growth hormones to help capture solar energy while consequently increasing the photosynthetic efficiency of the seedlings. Lende *et al.* (2007) have observed in their findings that foliar spray of 100, 150 and 200 ppm vermiwash consistently increased leaf chlorophyll and nitrogen contents in soybean. Dhiraj and Kumar (2012) have also reported that foliar spray of botanicals increased chlorophyll a and b content in mulberry plants. The positive effect of vermi extract on plant growth is largely associated with its N (NO_3^-) content and the presence of gibberellins and increased nutrient uptake by plants (Pant *et al.,* 2011).

Table 9: Effect of coffee husk vermiwash foliar spray on seedling growth attributes of *M.stenopetala* and *J. curcas*

Species	**LCa (µ/ml)**	**LCb (µ/ml)**	**PL (cm)**	**LN (n)**	**SG(mm)**	**SFW (g)**	**SDW (g)**	**RFW (g)**	**RDW (g)**
M.stenopetala	6.48[a]	2.54[a]	21.88[a]	8.16[a]	6.67[a]	6.17[b]	1.09[b]	8.53[a]	0.88[a]
J. curcas	4.01[b]	1.84[b]	18.75[b]	3.71[b]	5.34[b]	11.26[a]	1.83[a]	1.53[b]	0.23[b]
CV (%)	14.27	14.33	12.82	8.87	2.97	16.60	16.54	5.10	8.86
LSD (5%)	0.57	0.24	2.00	0.40	0.14	1.11	0.19	0.20	0.04

Means within a column represented by same letter are not significantly different at P< 0.05.

LCa= leaf chlorophyll a, LCb= leaf chlorophyll b, PL = plant height, LN= leaf number, SG= stem girth,

SFW= shoot fresh weight, SDW = shoot dry weight, RFW= root fresh weight, RDW= root dry weight

4.3.2. Seedling shoots length

The interaction of species and coffee husk vermiwash rate didn't significantly affect plant height (Appendix 5). However, the main effect of species (P=0.004) and coffee husk vermiwash rate (P=0.0056) significantly affected plant height (Table 9 and Appendix 5). Accordingly, *M.stenopetala* seedling showed higher main stem length compared to *J.curcas* (Table 9). The difference in seedling stem length could be due to species difference or due to both vermiwash influences. *M.stenopetala* showed taller plant height than *J.curcas.* In line with this, it has been reported that vermiwash application enhances nutrient uptake and growth promoting substances (Ansari and Sukhraj, 2010; Hatti *et al.,* 2010).

As illustrated in Table 10 increased coffee husk vermiwash rate significantly (P =0.0056) affected seedling plant height which consequently increased with increasing coffee husk vermiwash rate. Application of 10, 20, 30, and 40 % of coffee husk vermiwash improved plant height by about 4.31, 4.75, 19.71, and 32.20 percent over the control. This difference could be attributed to increased level of nutrients translocated in to plant tissues owing to increased rate of vermiwash application. Similar results have been reported by Ansari and Sukhraj (2010) indicating that vermiwash application resulted in maximum plant height of Okra (*Abelmoschus esculentus*) (about 42.33 $\pm$ 02.52) as compared to the control (31.67 $\pm$ 03.79). The increased plant height could be associated with the fact vermiwash contains a considerable level of plant growth promoters, auxins, gibberellins-like substances (Ansari and Sukhraj, 2010), high level of macro and micro nutrients (Hatti *et al.,* 2010), which positively influence nutrient uptake by roots and plant physiology as a whole by improving soil structure, and fertility.

Table 10: Seedling growth attributes of *M.stenopetala* and *J.curcas* as influenced by coffee husk vermiwash rate

Rate %(v/v)	LCb (µ/ml)	PH(cm)	LN (n)	SG (mm)	SDW (g)	RFW (g)	RDW (g)
Control (0)	1.61^{d}	18.11^{c}	5.19^{c}	5.58^{d}	1.21^{c}	4.57^{d}	0.48^{c}
10	2.01^{c}	18.89^{bc}	5.57^{bc}	5.83^{c}	1.34^{c}	4.88^{cd}	0.52^{bc}
20	2.23^{bc}	18.97^{bc}	5.98^{ab}	6.05^{b}	1.40^{bc}	5.02^{bc}	0.57^{ab}
30	2.46^{ab}	21.68^{ab}	6.47^{a}	6.23^{ab}	1.65^{ab}	5.27^{ab}	0.59^{a}
40	2.64^{a}	23.94^{a}	6.48^{a}	6.35^{a}	1.72^{a}	5.42^{a}	0.61^{a}
CV (%)	14.33	12.82	8.87	2.97	16.54	5.10	8.86
LSD (5%)	0.38	3.16	0.64	0.22	0.29	0.31	0.06

Means followed by the same letter(s) are not significantly different at P<0.05

LCb= leaf chlorophyll b, PH = plant height, LN= leaf number, SG= stem girth, SDW = shoot dry weight, RFW= root fresh weight, RDW= root dry weight

4.3.3. Leaf number

The interaction of species and coffee husk vermiwash rate didn't significantly affect seedling leaf number (Appendix 5). The main effect of plant species (P<0.0001) however, significantly affected leaf number (Table 9 and Appendix 5). More leaf number per seedling was observed for *M.stenopetala* (8.16) than did for *J.curcas* (3.71). This might be attributed to the genetic difference in leaf formation and /or ability to uptake vermiwash derived substances.

Moreover, coffee husk vermiwash rate significantly affected (P=0.001) leaf number of *M.stenopetala* and *J.curcas* seedlings (Table 10 and Appendix 5). Coffee husk vermiwash at 10, 20, 30, and 40 % increased leaf number by 7.30, 15.22, 24.67, and 24.86 percent, respectively over the control. This result is in agreement with the work of Suthar (2010), who reported that maximum number of leaves per *Cyamopsis tertagonoloba* seedling was observed due to 100% vermiwash (72.48%) compared to distilled water (control). Ansari and Sukhraj (2010) have also reported that application of *E.fetida* vermiwash to Okra

(*Abelmoschus esculentus*) more increased the number of leaves per plant (11 $\pm$ 0.00) than the control (09 $\pm$ 2.53). This could be attributed to the presence and impact of auxins-like earthworm-derived substances and macro and micro nutrients which improve the physical conditions of the medium for plant growth and nutrient uptake (Hatti *et al.,* 2010) and, consequently, improved level of chlorophyll pigment and leaf development (Suthar, 2010).

4.3.4. Seedling stem girth

The interaction of species and coffee husk vermiwash rate was not significant for seedling stem girth (Appendix 5). However, seedling stem girth was significantly affected by species ($P<0.0001$) (Table 9 and Appendix 5). Hence, compared to *J.curcas* (5.34 mm), *M.stenopetala* seedling had thicker stems (6.67 mm). The difference in stem girth could be linked with and influenced by the fact that *M.stenopetala* has thick swollen tap root system, a strategy to store and transport more water from its root tissue to the upper vegetative organ in order to have healthy plant growth in the future than does *J.curcas*.

As depicted in Table 10, seedling stem girth was significantly ($P<0.0001$) influenced by coffee husk vermiwash rate. Stem girth improve by 4.48, 8.42, 11.65 and 13.80 percent with increased vermiwash rate from 10, 20, 30, and 40 %(v/v) from 10 to 40%. The positive response to elevated vermiwash rate can be attributed to stimulatory effect of growth promoting substances and microorganisms within the coffee husk vermiwash. Suthar (2010) has reported that optimum plant growth (root length, plant height , shoot/root ratio and leaves per plant) resulted due to 100% vermiwash trial compared to 50% vermiwash, 5% urea solution and distilled water. According to Pant *et al*. (2011), vermi extracts serve both as a supplemental source of plant nutrients and an enhancer of soil biological properties which consequently give better plant biomass development.

4.3.5. Shoot fresh weight

The interaction effect of species and coffee husk vermiwash rate was not significant for shoot fresh weight of seedlings. Similarly, coffee husk vermiwash rate didn't significantly contribute to shoot fresh weight (Appendix 5). However, the main effect of species ($P<0.0001$) significantly affected seedling shoot fresh weight (Table 9 and Appendix 5). The observed difference between the two species can be attributed to their genetic difference. Hence, larger shoots fresh weight was observed for *J.curcas* due to its larger leaf area than did *M.stenopetala*.

4.3.6 Shoot dry weight

The two way interaction effect of species and vermiwash rate was not significant for seedling shoot dry weight. The main factors (species ($P<0.0001$) and coffee husk vermiwash rate ($P=0.0082$), however, significantly affected seedling shoot dry weight (Table 9, 10 and Appendix 5). The increased shoot dry biomass response in line with vermiwash rate might be due to the incorporation of high amount of micro-and macronutrients in to the plant tissues (Hatti *et al.,* 2010). Dhiraj and Kumar (2012) have also explained that foliar nutrients are readily mobilized and easily utilized directly in to plant leaves which consequently increase nutrient efficiency and uptake, increase cellular activities at all levels while increasing the rate of photosynthesis.

4.3.7. Root length

Root length was significantly affected by the interaction between species and vermiwash rate as well as the main effects of species, and coffee husk vermiwash rate ($P<0.0001$) (Table 11 and Appendix 5). The maximum seedling root length was recorded for *M.stenopetala* at highest rate of vermiwash application (30 and 40 %), compared to the other treatment combinations (Table 11). In contrast, the shortest root length was obtained due to the control (without vermiwash treatment) in *J.curcas*. Significant difference with in root length of both

species could be explained by the contribution of vermiwash as a beneficial seedling growth enhancer. Suthar (2010) has reported that 100% vermiwash treated *Cyamopsis tertagonoloba* seedlings showed about 47.4% more root length than urea 5% solution. According to Hatti *et al.* (2010) the vermiwash contains high level of macro and micronutrients, and growth promoting hormone like substances. This could be the case for more root elongation with increasing rate of vermiwash in the present study.

Table 11: Root length of *M.stenopetala* and *J.curcas* seedling as influenced by the interaction effect of species and coffee husk vermiwash rate

Species	**Coffee husk vermiwash rate %(v/v)**	**Root length (cm)**
M.stenopetala	0	8.16[d]
M.stenopetala	10	10.21[c]
M.stenopetala	20	11.39[b]
M.stenopetala	30	12.90[a]
M.stenopetala	40	13.66[a]
J.curcas	0	4.48[g]
J.curcas	10	5.70[f]
J.curcas	20	6.58[e]
J.curcas	30	8.43[d]
J.curcas	40	9.53[c]
CV (%)		1.26
LSD (5%)		0.81

Means followed by same letter(s) are not significantly different at P<0.05

4.3.8. Root fresh weight

The interaction between species and vermiwash rate didn't significantly affect seedling root fresh weight (Appendix 5). However, the main effects of species (P<0.0001) and vermiwash rate (P=0.0002) significantly affected root fresh weight (Table 9, 10 and Appendix 5). Hence,

M.stenopetala seedling root fresh weight was higher than that of *J.curcas* (Table 9). This might be linked with its thick stem diameter and swollen root system. Moreover, root fresh weight improved in line with increased coffee husk vermiwash rate (Table 10). As a result, maximum root fresh weight was observed due to 40 % followed by 30% compared to the other treatments. The observed root fresh weight improvement vermiwash rate might be attributed to the enrichment of growth promoting substances such as cytokinins, auxins, amino acids, vitamins, and enzymes (Suthar, 2010) and high level of macro and micronutrients (Hatti *et al.*, 2010) which in turn contributed for more water absorption.

4.3.9. Root dry weight

Root dry weight exhibited the same trend as root fresh weight. Accordingly, the interaction of species and vermiwash rate didn't significantly affect seedling root dry weight (Appendix 5). The main effects of species ($P<0.0001$) and vermiwash rate ($P=0.0014$), however, significantly affected seedling root dry weight (Table 9, 10 and Appendix 5). This investigation indicated that *M.stenopetala* had more root dry weight than *J.curcas,* which could possibly be associated with its increased growth of root cells/tissues (Table 9). Similarly, increased coffee husk vermiwash rate improved seedling root dry weight more effective than the control (Table 10). The difference in root dry weight might be associated to photosynthesis efficiency linked to chlorophyll content. This is an indication that vermiwash would enhance the rate of establishment of *M.stenopetala* and *J.curcas* seedlings when transferred to the field. The high level of macro and micronutrients in the vermiwash (Hatti *et al.*, 2010) might have been translocated to the plant biomass and, hence, promoted root growth. Moreover, Suthar (2010) indicated that C*yamopsis tertagonoloba* seedlings treated with 100% vermiwash foliar spray showed the maximum level of total protein, total soluble sugars and starch in their tissues, compared to the control. Therefore, the presence of higher root biomass might be an indication of good establishment in the field.

5. SUMMARY AND CONCLUSIONS

Coffee husk, a byproduct from dry coffee processing, is considered as a waste consequently resulting in environmental pollution, which otherwise would have been utilized as a source of organic matter for plants to grow. Utilization of coffee husk contributes essential soil nutrients to improve soil and plant productivity while avoiding environmental risks. Coffee husk utilization using different composting systems and application rates is helpful to optimize the potential contribution of the product already considered 'waste'.

In line with this the present study was conducted at Jimma University College of Agriculture and Veterinary Medicine during 2011/12 season to assess the growth responses of *M.stenopetala* and *J.curcas* as candidate plant species to application of different coffee husk compost type, and coffee husk vermiwash at different rates. *M.stenopetala* and *J.curcas* are claimed to be ideal for house hold food security and a renewable biofuel source, respectively. The three compost types, namely, vermicompost, EM compost, and conventional compost were applied at five rates (0, 10, 20, 30, and 40 %) (v/v). Besides, the coffee husk vermiwash foliar spray was also tested at five rates (0, 10, 20, 30, and 40 %(v/v)) on both species.

The results of physiochemical analysis of coffee husk compost-soil mixture before planting showed improved quality of the rooting media. As a result, coffee husk vermicompost at 40% contributed for maximum pH, OM, TN, and AP, whereas maximum EC and OC was observed due to incorporation of coffee husk conventional compost at 40 %.

The findings of the present study revealed the existence of significant responses in terms of plant growth. Generally, species, coffee husk compost types, coffee husk vermiwash foliar spray, and their respective rates showed significant influences on growth and quality attributes of *M.stenopetala* and *J.curcas* seedlings. Maximum seedling chlorophyll a and b was observed for *M.stenopetala* due to application of coffee husk vermicompost, which was statistically similar to with coffee husk conventional and EM compost and from *J.curcas* with coffee husk vermicompost and coffee husk EM compost.

The maximum shoot fresh and dry weight was recorded from *J.curcas* due to coffee husk vermicompost incorporation compared to *M.stenopetala* irrespective of compost types. Statistically, *J.curcas* gained similar shoot dry weight due to coffee husk conventional compost incorporation.

Coffee husk vermicompost at the highest rate (40 %) resulted in maximum root length in *J.curcas* which was statistically similar to coffee husk EM compost at 30, and 40%, and for *M.stenopetala* due to coffee husk vermicompost and coffee husk conventional compost at 40 %. The maximum seedling root fresh weight was observed for coffee husk vermicompost at 40 %(v/v) incorporation in *M.stenopetala*.

Maximum *M.stenopetala* seedling root dry weight was observed due to application of coffee husk vermicompost which was statistically at par with coffee husk conventional compost incorporation. Whereas the lowest root dry weight was observed for *J.curcas* due to all coffee husk compost types.

Vermiwash foliar spray at 30 and 40 %(v/v) resulted in maximum leaf chlorophyll b, plant height , stem girth, shoot dry weight and root fresh weight. Whereas, 20, 30 and 40 %(v/v) vermiwash foliar spray exhibited higher leaf number and root dry weight.

In conclusions, the utilization of coffee husk vermicompost improved the pot soil mixture for seedling growth better than coffee husk conventional and EM compost. Consequently, coffee husk vermicompost application at 40 %(v/v) resulted in maximum seedling growth attributes and, therefore, was the best. On the other hand, application of coffee husk vermiwash foliar spray at 30 and 40 %(v/v) was found to be economical. Therefore, coffee husk compost which demands low labour and simple technology input, can be an opportunity in coffee growing areas of the country for better seedling growth and performance in nursery and /or back yard garden. Besides, its use as a source of soil organic matter, composting coffee husk may also address problems associate with environmental pollution.

6. FUTURE LINE OF WORK

- ⇨ Effects of coffee husk vermicompost and vermiwash on nutritional quality of the tested plant species need to be studied.
- ⇨ In order to maximize benefit of coffee husk vermicomposting, incorporation of cow dung and/or other bulking agents might be helpful for an enhanced earth worm and microbial decomposition.
- ⇨ The current study needs to be repeated for two or more seasons and at different locations to draw a reliable conclusion.

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Appendix

Appendix Table 1: Physical and chemical properties of the soil mixture before planting allotted on treatment pots

Compost-Soil code	Compost rate %(v/v)	Block	pH	EC(ds/m)	%OC	%OM	%TN	AP(ppm)	K
CHVC	0	1	5.28	0.17	4.15	10.12	0.46	6.29	1.26
CHVC	10	1	6.86	0.44	7.20	18.21	0.71	11.71	2.34
CHVC	20	1	7.46	0.83	9.35	24.94	1.25	45.47	9.09
CHVC	30	1	8.29	0.99	11.21	31.44	1.49	68.95	13.79
CHVC	40	1	8.60	1.25	17.11	40.98	2.05	112.44	22.49
CHVC	0	2	5.23	0.18	4.13	10.11	0.46	6.25	1.25
CHVC	10	2	6.82	0.43	7.15	14.26	0.71	11.82	2.36
CHVC	20	2	7.40	0.85	9.30	24.95	1.25	44.95	8.99
CHVC	30	2	8.28	0.98	11.16	31.44	1.58	69.1	13.82
CHVC	40	2	8.55	1.26	16.87	40.10	2.05	111.33	22.27
CHVC	0	3	5.27	0.45	4.21	10.11	0.46	6.22	1.24
CHVC	10	3	6.86	0.45	7.19	14.25	0.72	11.55	2.31
CHVC	20	3	7.50	0.84	9.40	23.45	1.26	44.33	8.87
CHVC	30	3	8.39	0.98	11.23	31.45	1.51	68.88	13.78
CHVC	40	3	8.73	1.23	17.35	40.41	2.06	110	22.00
CHEMC	0	1	5.25	0.17	4.19	10.11	0.46	6.19	1.24
CHEMC	10	1	5.83	0.29	8.30	14.25	0.80	8.19	1.64
CHEMC	20	1	5.90	0.38	14.30	16.04	0.96	38.9	7.78
CHEMC	30	1	6.55	0.55	15.50	19.24	1.12	52.25	10.45
CHEMC	40	1	6.83	0.87	22.30	19.96	1.53	96.38	19.28
CHEMC	0	2	5.25	0.16	4.13	10.10	0.46	6.22	1.24
CHEMC	10	2	5.83	0.30	8.27	14.25	0.81	9.47	1.89
CHEMC	20	2	5.90	0.39	14.47	16.04	0.97	38.34	7.67
CHEMC	30	2	6.50	0.54	15.50	19.25	1.12	55.44	11.09
CHEMC	40	2	6.76	0.88	22.12	19.96	1.49	93.49	18.70
CHEMC	0	3	5.30	0.18	4.22	10.10	0.46	6.19	1.24
CHEMC	10	3	5.81	0.28	8.27	14.26	0.79	8.41	1.68

CHEMC	20	3	5.95	0.39	14.50	16.03	0.96	39.28	7.86
CHEMC	30	3	6.55	0.56	15.48	19.25	1.24	59.29	11.86
CHEMC	40	3	6.95	0.89	22.20	19.96	1.55	98.41	19.68
CHCC	0	1	5.30	0.18	4.21	10.12	0.46	6.21	1.24
CHCC	10	1	6.15	0.37	8.35	16.25	0.71	7.75	1.55
CHCC	20	1	6.70	0.85	13.66	19.25	1.25	31.33	6.27
CHCC	30	1	7.55	1.11	15.60	24.95	1.42	45.21	9.04
CHCC	40	1	8.03	1.36	23.80	31.29	1.66	84.11	16.82
CHCC	0	2	5.20	0.17	5.37	10.15	0.47	6.22	1.24
CHCC	10	2	6.05	0.38	8.27	16.10	0.72	7.77	1.55
CHCC	20	2	6.60	0.84	13.55	19.30	1.30	30.22	6.04
CHCC	30	2	7.45	1.10	15.50	25.61	1.51	44.28	8.86
CHCC	40	2	8.04	1.35	23.77	32.22	1.70	85.29	17.06
CHCC	0	3	5.28	0.17	4.28	10.14	0.46	6.14	1.23
CHCC	10	3	6.10	0.37	8.40	16.32	0.73	7.95	1.59
CHCC	20	3	6.65	0.86	13.60	19.50	1.28	30.15	6.03
CHCC	30	3	7.50	1.12	15.60	25.20	1.45	44.18	8.84
CHCC	40	3	8.10	1.37	24.10	32.33	1.69	85.27	17.05

CHVC= coffee husk vermicompost, CHEMC= coffee husk EM compost, CHCC= coffee husk conventional compost, pH= potential of hydrogen, Ec (ds/m) = Electrical Conductivity, %OC =Percent of Organic Carbon, %TN= Percent of Total Nitrogen, AP(ppm)= Available Phosphorus parts per million, K= Exchangeable Potassium

Appendix Table 2: Treatment combination for the experiment, effect of coffee husk composts on *M. stenopetala* and *J. curcas* seedling growth attributes

Treatments	**Species**	**Coffee husk compost types**	**Coffee husk compost rate % (v/v)**
T1= S1M1C0	*M. stenopetala*	Vermicompost	0
T2= S1M1C1	*M. stenopetala*	Vermicompost	10
T3=S1M1C2	*M. stenopetala*	Vermicompost	20
T4=S1M1C3	*M. stenopetala*	Vermicompost	30
T5=S1M1C4	*M. stenopetala*	Vermicompost	40
T6=S1M2C0	*M. stenopetala*	EM compost	0
T7=S1M2C1	*M. stenopetala*	EM compost	10
T8=S1M2C2	*M. stenopetala*	EM compost	20
T9=S1M2C3	*M. stenopetala*	EM compost	30
T10=S1M2C4	*M. stenopetala*	EM compost	40
T11=S1M3C0	*M. stenopetala*	Conventional compost	0
T12=S1M3C1	*M. stenopetala*	Conventional compost	10
T13=S1M3C2	*M. stenopetala*	Conventional compost	20
T14=S1M3C3	*M. stenopetala*	Conventional compost	30
T15=S1M3C4	*M. stenopetala*	Conventional compost	40
T16 = S2M1C0	*J. curcas*	Vermicompost	0

T17 = S2M1C1	*J. curcas*	Vermicompost	10
T18 =S2M1C2	*J. curcas*	Vermicompost	20
T 19=S2M1C3	*J. curcas*	Vermicompost	30
T20 =S2M1C4	*J. curcas*	Vermicompost	40
T 21=S2M2C0	*J. curcas*	EM compost	0
T22 =S2M2C1	*J. curcas*	EM compost	10
T23 =S2M2C2	*J. curcas*	EM compost	20
T24 =S2M2C3	*J. curcas*	EM compost	30
T25 =S2M2C4	*J. curcas*	EM compost	40
T26 =S2M3C0	*J. curcas*	Conventional compost	0
T27 =S2M3C1	*J. curcas*	Conventional compost	10
T28 =S2M3C2	*J. curcas*	Conventional compost	20
T29 =S2M3C3	*J. curcas*	Conventional compost	30
T30 =S2M3C4	*J. curcas*	Conventional compost	40

Appendix Table 3: Treatment combination for the experiment, effect of coffee husk vermiwash on *M. stenopetala* and *J. curcas* seedling growth attributes

Treatments	**Species**	**Treatment material**	**Vermiwash rate % (v/v)**
T1= S1C0	*M. stenopetala*	Vermiwash	0
T2= S1C1	*M. stenopetala*	Vermiwash	10
T3=S1C2	*M. stenopetala*	Vermiwash	20
T4=S1C3	*M. stenopetala*	Vermiwash	30
T5=S1C4	*M. stenopetala*	Vermiwash	40

T6 = S2C0	*J curcas*	Vermiwash	0
T7 = S2C1	*J curcas*	Vermiwash	10
T8 =S2C2	*J curcas*	Vermiwash	20
T9=S2C3	*J curcas*	Vermiwash	30
T10 =S2C4	*J curcas*	Vermiwash	40

Appendix Table 4: Mean square values of leaf chlorophyll a and b, plant height, leaf number, stem girth of *M.stenopetala and J.curcas* seedling as influenced by application of coffee husk compost

Source	**LCa**	**LCb**	**PH**	**LN**	**SG**
Species	67.01^{***}	3.72^{**}	59.85^{***}	306.29^{***}	86.16^{***}
Compost types	4.83^{ns}	0.28^{ns}	32.08^{***}	1.02^{***}	1.62^{*}
Species *compost types	13.56^{*}	3.65^{***}	1.38^{ns}	0.12^{ns}	0.41^{ns}
Compost rate	151.98^{***}	12.80^{***}	79.07^{***}	2.55^{***}	5.53^{***}
Species *Compost Rate	2.55^{ns}	0.09^{ns}	3.72^{ns}	0.04^{ns}	0.37^{ns}
Compost types * Compost Rate	1.15^{ns}	0.09^{ns}	3.10^{ns}	0.12^{ns}	0.33^{ns}
Species *Compost types * Compost Rate	2.78^{ns}	0.09^{ns}	3.22^{ns}	0.13^{ns}	0.05^{ns}

LCa= leaf chlorophyll a, LCb = leaf chlorophyll b, PH= plant height, LN= leaf number, SG= stem girth

Continued ….

Appendix Table 4: Mean square values of seedling growth quality attributes of *M.stenopetala* and *J.curcas* seedling due to application of coffee husk

Source	**SFW**	**SDW**	**RL**	**RFW**	**RDW**
Species	732.34^{***}	7.49^{***}	4.54^{*}	743.16^{***}	4.97^{***}
Compost types	9.63^{***}	0.34^{**}	8.00^{***}	2.68^{***}	0.12^{***}
Species *compost types	6.36^{**}	0.29^{*}	9.03^{***}	1.15^{**}	0.08^{***}
Compost rate	29.66^{***}	0.63^{***}	24.43^{***}	5.20^{***}	0.12^{***}
Species *Compost Rate	6.33^{***}	0.13^{*}	1.71^{ns}	0.76^{**}	0.03^{**}
Compost types * Compost Rate	1.15^{ns}	0.03^{ns}	2.50^{*}	0.72^{***}	0.00^{ns}
Species *Compost types * Compost Rate	0.62^{ns}	0.03^{ns}	1.71^{*}	0.68^{***}	0.01^{ns}

ns, *, ** and *** = Correlation is non significant, significant, very significant, very highly significant at 0.05, 0.01, 0.001probability level, respectively

SFW= shoot fresh weight, SDW = shoot dry weight, RL= root length, RFW= root fresh weight, RDW= root dry weight

Appendix Table 5: Mean square values of seedling growth quality attributes of *M.stenopetala* and *J.curcas* seedling as influenced by application of coffee husk vermiwash foliar spray

Source	LCa	LCb	PL	LN	SG	SFW	SDW	RL	RFW	RDW
Species	45.68***	3.69***	73.41**	148.52***	13.45***	194.21***	4.09***	139.88***	367.92***	3.16***
Rate	0.13^{ns}	0.97***	35.57**	1.91**	0.57***	3.95^{ns}	0.28**	26.59***	0.66***	0.02***
Species *Rate	0.89^{ns}	0.26^{ns}	0.61^{ns}	0.63^{ns}	0.01^{ns}	0.31^{ns}	0.04^{ns}	0.28***	0.05^{ns}	0.00^{ns}

ns, *, ** and *** = non- significant, significant, very significant, very highly at 0.05, 0.01, 0.001probability level, respectively

LCa= leaf chlorophyll a, LCb = leaf chlorophyll b, PL = plant height, LN= leaf number, SG= stem girth,

SFW= shoot fresh weight, SDW = shoot dry weight, RL= root length, RFW= root fresh weight, RDW= root dry weight

Appendix Table 6: Pearson Correlation Coefficients, N = 90, Prob > |r| under H0: Rho=0, for the experiment of the effect of coffee husk compost on *M.stenopetala* and *J.curcas* seedling growth.

	pH	Ec	OC	Om	TN	AP	k	LCa	LCb	PL	LN	SG	SFW	SDW	RL	RFW	RDW
pH	1	0.92***	0.64***	0.96***	0.91***	0.81***	0.81***	0.70***	0.67***	0.60***	0.19ns	0.34**	0.35**	0.39***	0.50***	0.17 ns	0.15 ns
Ec		1	0.79***	0.91***	0.94***	0.84***	0.84***	0.70***	0.67***	0.69***	0.18 ns	0.33**	0.32**	0.40***	0.55***	0.16 ns	0.09 ns
Oc			1	0.66***	0.83***	0.85***	0.85***	0.69***	0.70***	0.64***	0.13 ns	0.31**	0.26*	0.31**	0.56***	0.12 ns	-0.04 ns
Om				1	0.94***	0.85***	0.85***	0.70***	0.68***	0.59***	0.19 ns	0.33**	0.36**	0.40***	0.55***	0.17 ns	0.11ns
Tn					1	0.93***	0.93***	0.76***	0.76***	0.65***	0.19 ns	0.36**	0.35**	0.40***	0.61***	0.17 ns	0.07ns
AP						1	1.00	0.72***	0.75***	0.59***	0.18 ns	0.40***	0.36**	0.40***	0.67***	0.16 ns	0.00ns
K							1	0.72***	0.75***	0.59***	0.18ns	0.40***	0.36**	0.40***	0.67***	0.16 ns	-0.00ns
LCa								1	0.91***	0.41***	0.40***	0.46***	0.05ns	0.14ns	0.53***	0.39	0.31**
LCb									1	0.37***	0.33**	0.44***	0.07 ns	0.11ns	0.54***	0.32	0.23*
PL										1	-0.14	0.12ns	0.52***	0.54***	0.48***	-0.18 ns	-0.21*
LN											1	0.84***	-0.73***	-0.57***	0.00 ns	0.98***	0.87***
SG												1	-0.46***	-0.32**	0.15 ns	0.82***	0.69***
SFW													1	0.86***	0.40***	-.79***	-0.74***
SDW														1	0.44***	-0.62***	-0.58***
RL															1	-0.03ns	-0.06 ns
RFW																1	0.88
RDW																	1

pH= potential of hydrogen, Ec = Electrical Conductivity, OC =Percent of Organic Carbon, OM= Organic matter, TN= Percent of Total Nitrogen, AP= Available Phosphorus parts per million, LCa= leaf chlorophyll a, LCb = leaf chlorophyll b, PH = plant height, LN= leaf number, SG= stem girth, SFW= shoot fresh weight, SDW = shoot dry weight, RL= root length, RFW= root fresh weight, RDW= root dry weight.

ns, *, ** and *** = non significant, significant, very significant, very highly at 0.05, 0.01, 0.001probability level, respectively